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THE HOLMES LUBRICANT BEARING.

[*Report of the Committee on Science and the Arts.*]

[No. 1646.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, August 28, 1891.

The Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred, for examination,

PHILIP H. HOLMES' IMPROVED COMPOSITION FOR JOURNAL BEARINGS.

report that this invention aims to furnish a new composition of materials to be used in machinery as journal bearings, packings for sliding surfaces, etc., which possesses the requisite hardness to withstand the usual pressures, and also to offer a surface that, without the aid of oil or other lubricants, will reduce friction to a minimum and preclude the possibility of excessive or dangerous heating.

The principal element of this composition is graphite, reduced to a fine powder and freed as far as possible from all gritty matter.

To render this plastic and cohesive, it is mixed with wet wood pulp, in proportions according with the purpose of the finished article. In this condition the mass is forced into moulds of the desired shape, which latter are provided with ample drainage outlets to permit the escape of the water when the mass is subjected to pressure.

The wood fibre acts as an entangling and straining material to retain the fine graphite and prevent its escape with the water through the perforations of the mould.

After the composition has sustained the requisite pressure in the mould, it is removed and thoroughly dried, then it is immersed in a bath of hot drying oil until saturated, and thereafter baked in an oven until sufficiently hard.

The finished material has thus attained solidity and strength, and when reinforced by metallic support, is capable of withstanding heavy pressure, and becomes a safe and efficient anti-friction bearing for general use.

The uses to which this bearing material may be put are so very extensive, that it is manifestly impossible for your committee to make extensive tests in every direction to prove its efficiency, but so good an exhibit of its application has been afforded us, that safe conclusions may be drawn therefrom regarding its merits, in a range of mechanical uses covering a wide field.

For many valuable data respecting a great variety of tests to which the Holmes composition has been subjected during a period of more than two years, we submit numerous reports, hereto appended,* given by persons of excellent standing and mechanical ability, several of whom are prominent members of the Franklin Institute.

The well-known property of graphite, as a lubricant, has encouraged many attempts to so combine it with other materials, that it might be used as a complete substitute for metal bearings, but up to the present time, no one of

* Appended to the original report, on file, and accessible for reference.

these, save that of Mr. Holmes, has succeeded to the extent of securing even a limited adoption.

All prior inventors have incorporated in their product some unsuitable, and not infrequently some antagonistic material, which, upon trial, has caused the defeat of the object and consequent abandonment of the article.

This, however, does not apply to Mr. Holmes' efforts, for the two chief elements of his composition are both superior anti-friction materials, and the third (drying-oil), while aiding to strongly unite the other two, does not appreciably decrease their anti-friction value. Again, in the Holmes compound there is nothing that any degree of heat that can arise from frictional causes can injure, or by any possibility cause surrounding objects to ignite; therefore, the fire-risk, due to the over-heating of journals, will disappear in direct proportion to the use of these graphite bearings.

We find further that the ratio of friction with the Holmes bearings is much less than with well-oiled metal bearings, and greatly superior to the results obtained in common practice, thereby effecting a great saving in power even in comparison with the most carefully attended metal bearings. The coëfficient of friction of the Holmes bearing is practically constant, being no greater at starting than when running at any speed, which cannot be said of any oiled metal bearing.

This material may be moulded into any desired form with the nicest accuracy of finish, so that all forms may be infinitely duplicated with standard precision, without the necessity of touching a tool to them.

The remarkable qualities of this bearing material are strikingly exhibited in its application to the spinning frame, when the spindles are run at very high velocities. In this direction your committee have taken special pains to verify, by personal tests, the excellent results vouched for by others. Spindles running with unusually tight belts constantly ten hours a day for three weeks, at a speed of 8,400 revolutions per minute, did not heat, or show any perceptible wear either of the spindle or the graphite bearings.

Thus, through Mr. Holmes' invention, it has become

practicable to run an entire spinning plant without using a single oiled bearing, which realizes in economy, cleanliness and freedom from fire risks, conditions of inestimable value. Your committee have also practically tested the brushes made of this material for use upon dynamos, and found them practically indestructible, that they do not wear the commutators, and give most satisfactory results in every way.

Careful inspection of many bearings which have been running constantly throughout the day for several months, show, in no single instance, any appreciable wear either of journal or bearing, which fact is also abundantly testified to by others, whose observations have extended over one and two years in practical tests, showing the durability of these bearings to be very great.

All of the materials used in the Holmes composition are inexpensive, are obtainable in the open market, and their source of supply in the United States is practically inexhaustible.

These facts remove all doubt of the permanency of supply of this composition where its manufacture has once begun, and are also a safe guaranty of successful and economical production.

Your committee are not prepared at this time to set any limit to the usefulness of this graphite bearing, or to express an opinion regarding the ultimate weight per square inch of surface that may safely be applied to it, but are satisfied that the limit, if found at all, will only apply to such bearings as are essential to the very heaviest class of work, and which constitute only a very small part of the immense aggregate of machines and implements to be benefited thereby.

For these considerations we cheerfully accord to Mr. Philip H. Holmes, the inventor of this compound for journal bearings, and of its practical method of manufacture and application, the well-earned credit of having conceived and worked out to a high degree of excellence an improvement of rare importance and very great value, affecting almost the entire system of machinery construction in the

directions of economy of power, extended durability, immunity from fire caused by friction, and extreme cleanliness, and contributing substantially to precision of operation and the increase in quality and quantity of product.

This achievement entitles the inventor to the fullest recognition by the Franklin Institute, and to receive its highest award, the Elliott Cresson Gold Medal, which accordingly is respectfully recommended by the committee.

H. R. HEYL, *Chairman*,
J. SELLERS BANCROFT,
THOS. P. CONARD,
PHILIP H. FOWLER,
LUTHER L. CHENEY,
STOCKTON BATES,
H. W. SPANGLER,
S. M. VAUCLAIN.

Adopted, September 2, 1891.

S. LLOYD WIEGAND,
Chairman of the Committee on Science and the Arts.

APPENDIX.

[Prof. Coleman Sellers having made a report on the Holmes fibre-graphite lubricant bearings previous to the examination by the Committee on Science and the Arts of the Franklin Institute, which was submitted with other data for the committee's information, the following extracts therefrom may usefully supplement the committee's report.]

* * * *

At your request I visited the exhibition of the Holmes fibre-graphite, as shown at 123 North Fifth Street, Philadelphia. I have carefully looked into the merits of this material.

The object of the invention is to furnish a material of low coëfficient of friction that can be used in machinery without the necessity of oiling, to avoid the inconvenience that arises from oil in some cases, and yet without material loss of power, and without danger of heating, and thereby igniting the surrounding woodwork. It is a well-known fact that many fires in factories have originated from heated bearings, and railroad practice shows daily examples of the ignition of the oil on the journals of car axles, when they have begun to cut and heat.

This material, while capable of being used without oil, is not injured by the application of oil, may be lubricated when the pressure is great, and can be depended on not to cut should the bearing run dry after having been lubricated with oil.

The ingredient made use of by Mr. Holmes is plumbago in a finely-divided condition, and as free from all gritty particles as it is possible to make it. Plumbago as a lubricant has been known for a very long time and many attempts have been made to solidify it in a manner to permit the solidified material being worked and made into the form necessary to answer the purpose of journal bearings or flat sliding surfaces, for all cases where lubrication is resorted to to diminish friction.

The mode of preparation of Holmes' anti-friction material consists essentially in thoroughly mixing it with wood fibre in a moist condition, and pressing the mixed fibre and graphite into a mould of proper form. The compound is of very considerable strength, quite able, if sufficiently reinforced, to bear pressure and capable also of being lubricated if desired, and also capable of running continuously under water as is required in the steps of turbine wheels and other places.

The use of oil as a lubricant in machines is to separate the rubbing parts and to diminish the friction of metal upon metal by an intervening film of the lubricant.

If the oil is furnished in sufficient quantity to cause entire separation of the metals, the friction may be reduced to a measure of the viscidity of the unguent used. Where oil is administered in less quantity, however, the friction of metal upon metal is usually resistance due to interlocking particles of the revolving and stationary parts. The oil used as a lubricant in most cases finds its way from the bearing loaded with the metal that is gradually torn from either the revolving shaft or the box in which it runs.

It is a well-known fact that heavy lubricants effect a better separation for the metals than the finer lubricants, though it is also known that the power required to slide the surfaces one upon the other is much less with the more

limpid lubricant than with the thicker one, but at the same time the wear and tear of the metal may be greater.

For a long time engineers have been seeking for a substance that would be capable of being used as bearing surfaces and have a low coëfficient of friction, either with or without oil. From my several publications on this subject, it will be seen that I have always held to the opinion that if oil can be introduced in sufficient quantity and with sufficient degree of continuity to separate the revolving shaft from the journal bearing in which it revolves, it makes little difference what metal is used for the box; therefore, for ordinary line shafting, I have always advocated the use of cast iron as being the cheapest and most serviceable bearing.

The friction in line shafting varies according to the attention paid to oiling, and many experiments have been tried and the result has been reached pointing towards the necessity of the utmost care in lubrication, and also frequent lubrication to diminish the friction of the bearings.

The experiments I have been able to make with the Holmes material have satisfied me that the cöefficient of friction is lower than that of many oiled bearings in good condition and well attended to. It is undoubtedly lower than with metal bearings as usually operated, with moderate attention and poor qualities of oil. The graphite as compounded will bear lubrication and runs well under water, not being affected by moisture, oil, or by many chemicals, such as acids, ammonia, or any of the chemical substance liable to be found in manufacturing establishments.

It seems to be constant in its frictional resistance when dry under any given pressure, and this quality alone is of importance, as it brings the frictional loss to a constant, while doing away with the cost of oil and the need of personal attention to the moving parts.

It is constant in its small frictional resistance whether warm or cold, while it does not run lighter when warm by use as some oiled bearings do. Its uniform action is better than many oiled bearings and very much safer. The constant amount of frictional resistance being known, can be provided for in the power of the machine.

More than forty years of my life have been spent among machinery and devoted to solving questions involving friction, having contributed no little to bringing line shafting to its present high state of excellence. I have had opportunities to experiment with many kinds of journal-bearings, from glass through the several metals and alloys of metals, to the fluid bearings and modification of oiling devices, as well as the numerous applications of plumbago as a lubricant or the chief component of frictional surfaces. The present composition is new to me and presents advantages that have not obtained with other applications of graphite as a lubricant, that I have tried.

The question of frictional resistance may be considered as a necessary drawback in all mechanical devices, and the best we can do is to reduce this frictional resistance to a minimum, either by presenting as rubbing surfaces materials which slide easily one upon the other, or render motion safe by means of lubricants. The best oils, while dimishing frictional resistance, do not, under ordinary conditions, prevent the wear of metals rubbing one on the other, as is well known by all engineers. It is then, in many cases, a question of how much we can afford to pay for power lost through the use of lubricants that prevent wear of the rubbing parts, or how much wear can be permitted with less loss in the power required to drive the machinery.

The Holmes mixture of graphite gives a substance that can readily be moulded into shape or furnished in timber, roughed to size and capable of being worked into shape with the ordinary tools adapted to cutting wood or metal.

The applications that can be made of this substance with marked advantage extend over all cases of rubbing surfaces. It shows no appreciable wear when running at a surface speed of 1,000 feet per minute and under a pressure of fifty pounds per square inch, and it is generally assumed that when the pressure on rubbing surfaces is less than fifty pounds per square inch, the viscidity of the unguent acts as a sensible retardent. Where the pressure amounts to only a few pounds per square inch on the rubbing sur

faces, the oil acts so much as a retardent as to make it advisable, wherever possible, to dispense with it altogether.

Besides the cost of the lubricant used in a large establishment, with the expectation of diminishing the frictional resistance, there is also the cost of the attention required to apply the lubricant, and to keep the parts clean. Beyond this there are many cases in which the lubricant itself is a source of danger, first as by some kinds of oil coming into contact with wood fibre, or by waste starting fires by spontaneous combustion, and oil also is often injurious to the material that is being worked in the factory.

To dispense with the oil in the case of metal bearings, however, where but little is required, and the speed of the rubbing surfaces is high, involves danger from heating, and many fires originate from hot boxes in factories, as they do continually from the hot boxes under cars on the railroads.

I find the Holmes preparation to be a substance that under light pressures, certainly has a lower frictional equivalent than metal surfaces under the best conditions, lubricated by oils other than of the most costly character. There seems to be, under those conditions, no appreciable wear either of the bearing or the spindle, or other sliding surface working upon this material, even when the velocity is very great, and so far as I have been able to determine, the heat generated by the friction is no greater than we find with many lubricated bearings that are under no greater pressure, but that have as great velocity.

I am unprepared at present to state how far the Holmes composition of graphite can be used under the severe pressures that occur in some cases in machinery, but even in that direction there seems to be a chance for excellent results to be obtained where the material can be prevented from spreading by sufficiently firm surrounding walls.

I have examined with very great attention and care the action of loose pulleys upon shafts, the loose pulley being bushed with this Holmes material. I find that they run freely, do not show wear, give no indication of excessive heat under reasonable conditions of speed, and do away with the annoyance of oil, which, by the revolution of the pulley

is carried out to the revolving ends, and there thrown off and lost. For this one purpose alone the invention is of incalculable value, but the cases in which it can advantageously be applied are so numerous as to include all rapid moving frictional surfaces.

The readiness with which the material can be applied to this use, its good conducting power of electricity and the amount of heat it will bear, open up many uses for it other than as an anti-friction bearing.

If not hampered with too excessive cost charges in its introduction, it presents one of the cheapest forms of self-lubricating material that has yet been made known to me, and the very great saving, as well as the safety incident to its use in dispensing with oil, avoiding danger of fire, and the uncertainty of frictional resistance with lubricants, will make it economical in use, even with a sure profit of very considerable amount to the owners of the invention.

I look upon this as one of the most important improvements that has been made in material for bearings, and likely to work radical and important changes in machine construction. Besides, by its introduction to those applications where the avoidance of oil is desirable, the field of its usefulness would be practically unlimited. Thus where oil is to be avoided from danger of injury to fabrics, to cases where the heat is too great to permit lubrication (such as the axles of cars run into drying ovens), in the case of bearings that are inaccessible on account of situation or danger of approach, in the manufacture of explosives by machinery, etc. Its use in the rapid running of spindles of cotton mills on spinning frames leaves nothing to be desired, while the possible use in draw frames of shell rolls running free without oil, is a strikingly happy application of the invention.

Hinges for heavy doors can be bushed with the material to work noiselessly and freely. Sheaves for window cords, and the sheaves that are inaccessible in dumb-waiters in houses can be so bushed to run freely and without danger.

An invention of this kind, diminishing the use of lubrication, diminishes the cost of machine construction by doing

away with the many devices incident to oil, oil cups, oil hole-covers, the oil holes themselves which have to be drilled and carefully placed, oil tubes to lead the lubricant to the inaccessible parts of machinery, as well as the cost of the personal attention, and the cost of the lubricant required to keep the machinery in working order.

I have carefully considered the statements made by those who have used the Holmes fibre-graphite compound for a comparatively long period and find no exaggerated claims of durability, nor any that are inconsistent with what may be expected from the nature of the substance.

Comparing this substance with the so-called anti-friction metals used to line or cover the bearing surfaces, I find from some experiments of my own, that when emery of the best quality is introduced between a graphite block and a metal plate, the cutting action of the emery is of very short duration as compared to the use of the same emery on the same metal, the rubbing block loaded with emery being made of the best anti-friction metal. These so-called anti-friction metals, hold the emery and the cutting power continues as long as the particles of stone imbedded will last, but when applied to the block of fibre-graphite they seem immediately to become buried in the graphite, and the bearing substance itself furnishes a protection against cutting.

The experiments I have tried in this direction have all been favorable to the Holmes mixture, but one of the most important qualities connected with it is its ability to resist long-continued hammering action. I find that a solid block of the Holmes graphite mixture will bear an amount of hammering that would quite deform the surface of the metals commonly used for bearings.

The ideal bearing surface must be so different in its nature from the metal that slides upon it as to be unable to weld or unite therewith, and at the same time it must, in many cases, be able to bear long-continued vibratory, (called hammering) action, that is incident to unbalanced machinery and much of the services on railroads.

The value of paper stock as a substitute for metal in engineering construction is instanced in the durability of

paper car wheels, hence in a compound of vegetable fibre, intimately mixed with graphite with binding or felting qualities of sufficient power, we cannot but anticipate durability.

The ease with which the Holmes compound can be applied in practice is favorable to its introduction, and I have no reason to doubt the statement made by those who have used it for a considerable length of time and anticipate for it a durability more favorable to the user than to the manufacturer of the material.

Being uninformed as to what the owners propose doing with the invention in the direction of its introduction, I see in it capabilities of numerous producing establishments required to supply the demand that must sooner or later arise, when the good quality of the graphite bearing comes to be known. The application will increase with the means of production, and the saving in cost of its application as compared to anti-friction metal linings that do not dispense with lubrication, is greatly in favor of the graphite.

If this substance, as now seems inevitable, will diminish fire risks, its use will in time be made obligatory in sufficient number of cases to insure its owners a valuable return for what I look upon as a very notable invention.

COLEMAN SELLERS, E.D.,
Consulting Engineer,
Prof. of Mechanics, Franklin Institute,
Prof. Engineering, Proctor Stevens Institute of Technology, etc.

THE DEVELOPMENT OF THE PIG IRON MANUFACTURE IN THE UNITED STATES.*

BY JOHN BIRKINBINE,
President, American Institute of Mining Engineers.

[*Concluded from p. 353.*]

The following remarks concerning the progress of the pig-iron industry and a prophecy as to its future appear in volume xv of the Tenth Census, namely, that of 1880, which is presented here to show how much more rapidly the industry has developed than was then anticipated would be the case six years ago, when it was written.

"In 1866 the United States had reached the production of Great Britain in 1835; that is to say, she was then thirty-one years behind the latter country. At the end of 1884 she was but twenty-one years behind England. And at the same rate of increase for both countries, the United States will be but fifteen years behind England in 1900, and will reach and pass her in 1950, the production of pig iron in each country for that year, as determined from the equation of their respective curves, being a little over 30,000,000 tons."

MR. HEWITT'S ESTIMATE.

In a paper read at a late meeting of the American Institute of Mining Engineers, in October, 1890, by its then President, Hon. Abram S. Hewitt, Table D was presented, showing the comparative rate of increase in population and pig iron production in the United States for six decades.

TABLE D.

Relative Increase of Population and Pig Iron Production.

Year.	*Production of Pig Iron, Gross Tons*	*Rate of Increase, Per Cent.*	*Population.*	*Rate of Increase.*
1830, ...	165,000	—	12,866,020	32·51
1840, ...	315,000	91	17,069,453	33·52
1850, ...	564,000	79	23,191,876	35·83
1860, ...	821,223	46	31,443,321	35·11
1870, ...	1,696,429	106	38,558,371	22·63
1880, ...	3,835,191	126	50,155,783	30·08
1890, ...	9,202,703	140	62,622,250	24·86

* A lecture delivered before the Franklin Institute.

This table, the writer says, "brings out the striking conclusion that the production of pig iron has always increased more rapidly than the population and that the ratio is an increasing one. Between 1830 and 1860, the production of iron increased twice as fast as the population. Between 1860 and 1890 it increased four times as rapidly, in reality over four times, thus proving that the national wealth continues to grow from decade to decade, at a rate of acceleration of which the world affords no previous example. Inasmuch as during all this time, we have imported iron in addition to our production, it follows that the consumption per capita has also increased more rapidly than population. In 1855, according to careful calculations, which I made at that time, we were consuming iron at the rate of 117 pounds per head; whereas, in 1890, the consumption has increased to rather more than 300 pounds per head, the whole of which, for the first time in our history, we are producing within our borders.

Great Britain, on the other hand, produces more iron than it consumes, and is still the largest per capita producer in the world. In 1889, with a production of 9,321,563 tons of 2,000 pounds, and with a population estimated at 38,000,000, the production reached the large figure of 495 pounds per head. Deducting the exports, Great Britain is now consuming 250 pounds per head against a consumption of 144 pounds in 1855. But the production of iron in Great Britain appears to be now very nearly stationary."

Mr. Hewitt anticipates fully as great development of the iron industry as I mention, for he says:

"I think it is safe to estimate, therefore, that in 1900 the world will require 35,000,000 gross tons of iron, of which the United States must supply forty-five per cent., and the other iron-producing countries the remainder, in the proportion of half to Great Britain and half to Germany, France, Belgium and the other smaller producers."

This prophecy means a production in the United States, in the year 1900, of 15,750,000 gross tons.

MR. ATKINSON'S ESTIMATE.

Mr. Edward Atkinson presents the following estimate concerning the prospective demand of the world for pig iron in the year 1900:

	Tons.	*Tons.*
Present production,		25,000,000
Increased consumption in the United States,	7,000,000	
Increased consumption in Great Britain, France, Germany and Belgium,	2,000,000	
Increased consumption in all the rest of the world,	6,000,000	
Total increase of demand,		15,000,000
Total supply required,		40,000,000

He says: "If then one may predict a continuance of this law of accelerating demand for the next eleven years, neither 40,000,000 nor 44,000,000 gross tons will suffice in the year 1900. If this increasing demand should continue, the supply must be 100 per cent. in excess of that which now prevails. The supply in 1900 must be 50,000,000 gross tons or 56,000,000 net tons. Who will supply it?"

For the reason heretofore given, I do not place the future output at as high a figure as either of the gentlemen named, but at either of the rates of increase indicated, there is an apparently bright future before those engaged in pig iron production, ore and coal mining, coking and other allied industries, who are in position to share in this growth, for every advance made must be with discretion and after a thorough investigation of existing and prospective competition.

The day has passed when iron can be successfully produced without improved appliances, both in construction and modern methods of operation. The blast furnace must supply what the consumer wants, and technical knowledge will keep close company with administrative ability in securing the increased output, to which all investigations point as a certainty.

PRODUCTION OF PIG IRON PER CAPITA.

Referring to the figures for 1860, 1870, 1880 and 1890 (see Table E), it will be interesting to consider the pig iron pro-

duction in the censuses named, and also the population of the country, to show what relations exist between population and production, and taking the figures presented, we find the following relation between the number of people and the tons of pig iron made, in each of the census years, in the several sections of the country, and also in the State of Pennsylvania. Reference is especially made to Pennsylvania, because of its being our own Commonwealth; because it has led, still leads, and will probably continue to lead all other States as a producer of pig iron.

We find that the census year 1860 shows a population of nearly 31,500,000, and a production of less than 1,000,000 tons of pig iron; that is, we produced one ton of pig iron for about every thirty-two inhabitants, but in 1870, while the population had increased about one-quarter, the production of pig iron had been nearly doubled, and in that year one ton of pig iron was produced for every twenty-one inhabitants. The census of 1880 shows a population of over 50,000,000 an increase of nearly one-third over 1870, and a production of pig iron eighty per cent. greater than in 1870. In this year one ton of pig iron was made for every fifteen inhabitants. The census of 1890 shows a population of nearly 62,500,000 and a production of over 8,500,000 gross tons of pig iron. This demonstrates that last year the United States produced one ton of pig iron for every seven and one-third inhabitants.

We may also investigate the distribution of the population and the pig iron production, in each of the four general divisions, following the early method on account of using the census of 1860. These divisions will be New England States, as generally accepted, including Maine and intermediate States to, and including, Connecticut.

The Middle States (New York, New Jersey, Pennsylvania and Delaware).

The Southern States, all States south of the Ohio and Potomac Rivers, and east of the Mississippi River, including Maryland and Louisiana.

The Western States, the rest of the country.

We then find that while the population of New England

increased practically 500,000 souls in each decade, the amount of pig iron produced was varied but slightly, and that this section made one ton of pig iron for every 118 inhabitants in 1860, and one ton for each 156 of its population in 1890.

TABLE E.

Distribution of Population and Production of Pig Iron, According to Census Returns of 1860, 1870, 1880 and 1890.

	1860.			1870.		
	Population.	Production of Pig Iron.	Inhabitants per Ton of Pig Iron.	Population.	Production of Pig Iron.	Inhabitants per Ton of Pig Iron.
United States, ...	31,443,321	987,559	31·84	38,558,371	1,832,876	21·04
Pennsylvania, ...	2,906,215 9·24	580,049 58·74	5·01	3,521,951 9·13	922,564 50·33	3·82
New England, ...	3,135,283 9·97	26,600 2·69	117·87	3,487,924 9·05	30,778 1·68	113·33
Middle States, ...	7,571,201 24·08	706,369 71·53	10·72	8,935,891 23·17	1,171,115 63·89	7·63
Southern States, . . .	9,981,480 31·74	100,761 10·20	89·06	10,859,955 29·16	164,768 8·99	65·91
Western States, . . .	10,755,357 34·21	153,829 15·58	69·92	15,274,671 39·62	466,215 25·44	32·76

	1880.			1890.		
United States, ...	50,155,783	3,375,911	14·86	62,622,250	8,553,374	7·32
Pennsylvania, ...	4,282,891 8·54	1,723,492 51·06	2·48	5,258,014 8·40	4,207,599 49·19	1·25
New England, ...	4,010,529 8·	27,640 ·82	145·10	4,700,745 7·51	30,162 ·35	155·85
Middle States, ...	10,643,486 21·22	2,143,833 63·50	4·96	12,869,293 20·55	4,657,670 54·45	2·76
Southern States, . . .	13,975,686 27·86	311,639 9·23	44·95	16,236,784 25·93	1,582,106 18·50	10·26
Western States, . . .	21,526,032 42·92	892,799 26·45	24·11	28,815,428 46·01	2,283,436 26·70	12·62

The Middle States, with a population of 7,500,000 in 1860, produced over 700,000 tons of pig iron or one ton for every eleven inhabitants, and in the next ten years the population had increased to nearly 9,000,000, while the production of pig iron exceeded 1,000,000 tons, so that

one ton of pig iron was produced for every seven and two-thirds inhabitants. A further increase in population in 1880 to over 10,500,000 and a pig iron output of over 2,000,000 tons, made the production of pig iron one ton for every five inhabitants. In 1890, a still further augmented population to nearly 13,000,000, and a production of nearly 4,750,000 tons of pig iron, was equivalent to one ton to every two and three-quarters inhabitants.

A marked increase is shown in the Southern States which, with a population of 10,000,000 in 1860, produced about 100,000 tons of pig iron, or one ton for every ninety-nine inhabitants; but an increase in the population to 10,750,000 in 1870, was met by an augmented production of pig iron nearly one and two-thirds times what it was ten years before, and one ton was produced for every sixty-six inhabitants; in 1880, the Southern States had a population of nearly 14,000,000, and nearly double the production of pig iron of 1870, so that one ton of pig iron was made for every forty-five inhabitants; in 1890, with a population of over 16,000,000 and a pig iron production of over 1,500,000 tons, the Southern States produced one ton of pig iron for every ten and one-quarter inhabitants.

In the Western States the increase of population has been more rapid, and although the development of the pig iron industry has been greater in amount than in the Southern States, it did not show the same relation per capita. In 1860, the population of the Western States was 10,750,000 inhabitants, and the production over 150,000 tons of pig iron; that is, one ton was produced for every seventy inhabitants; whereas, in 1870, the population was over 15,250,000 and the production nearly 500,000 tons of pig iron, or one ton for every thirty-two and three-quarters inhabitants. In 1880, the 21,500,000 inhabitants and nearly 900,000 tons of pig iron, made the proportion one ton to every twenty-four inhabitants in the Western States, and in 1890, the population was 28,750,000 inhabitants and the production over 2,250,000, or one ton to every twelve and two-thirds inhabitants.

The divisions of the country as given above, do not

properly represent the groupings of the American blast furnaces, and a comparison of the population and pig iron output, made in conformity with existing commercial relations would considerably alter the per capita output in certain sections. However, in the absence of any other generally accepted subdivision of the country, no effort will be made to follow the discussion in detail as to specific localities.

THE POSITION OF PENNSYLVANIA.

The query naturally suggested to Pennsylvanians is, if the United States has in the last thirty years increased its relative production of one ton of pig iron for every thirty-two inhabitants to one ton of pig iron to every seven and one-half inhabitants; and if the Middle States have similarly advanced from one ton to every eleven inhabitants to one ton for every two and one-quarter inhabitants, what has been, and what is, the position of Pennsylvania? Its population of less than 3,000,000 inhabitants in 1860 had increased to 5,250,000 in 1890, while its pig iron product of but little over 500,000 in 1860 was augmented to nearly 4,250,000 in 1890.

In 1860, Pennsylvania produced one ton of pig iron for every five inhabitants; in 1870, it made one ton of pig iron to every three and three-quarters inhabitants; in 1880, one ton was made for every two and one-half inhabitants, and in 1890 one ton for every one and one-quarter inhabitants.

The position of Pennsylvania is more marked when we remember that, according to Mr. James M. Swank, in *Iron in All Ages*, no iron was made in the State prior to 1692, and that was of such small extent that the exact location of the enterprise is not known. As a practical producer of iron, Pennsylvania's history does not commence until 1716, sixty-six years after the establishment of the industry in Massachusetts. It would also be well to note in this connection that until 1859 no pig iron was made in Pittsburgh, and yet in thirty-one years, the magnificent industry in Allegheny County has developed, until in 1890 a total of 1,337,309 gross tons were produced.

Another instance of remarkable development is in Illinois, no iron having been manufactured there until 1839, but in 1890, 701,106 gross tons were produced from fifteen furnaces located in that State.

Allegheny County, Pennsylvania, in which Pittsburgh is located, and Cook County, Illinois, in which Chicago and Joliet are located, are the two greatest producing centres, when compared with the areas covered, that we have in the United States from which reports are published. Their aggregate output was 22 per cent. of the total for 1890.

The Birmingham district of Alabama also represents very rapid development and produces a large amount of pig iron in a limited territory, but as the official statistics are not reported separately from those of the State of Alabama, no absolute statement is offered.

According to the *Iron Age*, the United States during October, 1891, was producing pig iron at the rate of 9,750,000 gross tons annually, and in commenting upon the contributors to this output, the following editorial statement is made: "The product of one great steel company, the Illinois Steel Company, was during the month of October nearly equal to that of all the coke furnaces in Alabama, Tennessee and Georgia put together, the aggregate in each case being a few hundred over 100,000 gross tons. The Carnegie firms, in Allegheny County, made about 82,000 tons in the same month."

A review of the above memoranda demonstrates the following:

In 1860, the production of pig iron in Pennsylvania per capita was nearly as great as that of the Middle States in 1880, twice that of the Southern States in 1890, and two and one-half times that of the Western States in 1890.

The per capita output of pig iron in the United States is now considerably less than that of Pennsylvania thirty years ago.

In three decades, the output of pig iron per capita in Pennsylvania has quadrupled, and that of the rest of the United States, in the same time, has not kept pace with the Keystone State; although the Western States show a some-

what accelerated growth of output per inhabitant, and the Southern States a remarkable increase in this particular. The oft prophesied annihilation of the blast furnaces of Pennsylvania and their removal to other localities, seems no nearer fulfilment than it was years ago.

Taking the production of pig iron in the United States in the future at one ton for each six inhabitants, (say) 375 pounds per capita annually, the Western States must double their output of pig iron and the Southern States increase their production fifty per cent. before they supply the requirements of their present population, if that population represents average consumers.

If Pennsylvania should not augment its annual output of pig iron one ton in the next decade, she would still, in all probability, head the list of producers, and contribute about one-third of the supply of the nation. With a wealth of fuel, ore and flux, with excellent transportation facilities to convey fuel, distant ores to, and the product from, the furnaces, and with a strong home market, the iron masters of the Keystone State are not in need of sympathy from prophets of evil; and only as the other sections of the country exceed the national per capita production, will inroads be made on the State's natural market; unless these sections fail to foster a development which makes the people consumers as well as producers.

I may be pardoned for calling attention to the words of the prophet, "Shall iron break the Northern iron and the steel," (Jeremiah xv: 12), as a question still unanswered affirmatively for the pig iron industry of the United States.

THE FUTURE SITUS.

A late publication, by Mr. Edward Atkinson, *The Future Situs of the Principal Iron Production of the World*, from which an excerpt was given concerning the probable output of pig iron in 1900, contains the following cautious prophecy as to "the future situs of the iron production of the world:"

"One may not venture yet to name the specific place or places. The survival of the fittest among the many enterprises now claiming public attention will soon determine it

in the emulation between the North, the South and the West.

"Suffice it that if one should stand upon the top of the highest peak among the Great Smoky Mountains in the heart of the Southern Appalachian chain, and could bring within his vison all that would come within a radius of seventy-five to 100 miles, he might be able to establish the centre of iron and steel production which would not be very far away from what has been called the 'centre of gravity' of the population of this country.

"If he could bring within his vision the whole configuration of the area enclosed within a circle of about 150 miles in diameter, centring on the Great Smoky Mountains, he might trace the lines made by the erosion of the rivers and the gaps in the ranges on which the rails may be laid to the northwest at the southern border of Ohio, and to the southeast on the way toward the Atlantic ports of South Carolina, over which the metal produced at the possible future centre of the iron production of this country may be distributed on the easiest grades, either for domestic consumption or for the supply of foreign markets."

The region referred to is known to abound in minerals suitable for conversion into pig iron and its stores of hidden wealth are probably much greater than is now recognized. But if American pig iron producers could be carried to the peak of the mountains referred to, and be shown all the wealth of the little world of from 40,000 to 80,000 square miles area, even this will hardly tempt them to believe, as far as the United States is concerned, the prophecy, which the text of the paper indicates, was made as much to formulate an argument against the present customs duties as to determine a situs.

To agree with Mr. Atkinson, we must assume that the development of the ores of the Eastern and Middle States have reached their maximum, that the great coal areas of Pennsylvania, Ohio, Indiana and Illinois are to see comparatively little future extension in mining operations for metallurgical uses, that the wonderful supply of iron ores of Michigan, Wisconsin and Minnesota, which in 1890 amounted

to over 9,000,000 gross tons, or more than half of what the entire country furnished, are to make but small advances in utilization; that the ores of Southern Missouri, Arkansas and Texas, and the coals near the border of Indian Territory, if developed, are not to be assembled in quantity sufficient for a large producing industry.

In addition, we must make no allowance for the exploitation of the excellent ore deposits of Wyoming, which are distant from Chicago less than fifty per cent. farther than where the present ore supply for furnaces near that city is obtained. We must give Colorado small margin for augmenting its iron industry, and omit serious consideration of utilizing the known minerals of Utah, and we must also leave out of our calculation the possibility of the Pacific States employing their recognized mineral resources on a liberal scale.

To accept Mr. Atkinson's situs, we must dismiss the illusion that the market is a most potent factor in the establishment of an iron industry, an *illusion* (?) that has caused capital to embark in iron production and manufacture at points like Chicago, where none of the raw materials are indigenous, but where they can be assembled advantageously and where unusual market facilities are offered.

If we endorse his conclusions as correct, we must question the business foresight of the Pennsylvania Steel Company, erecting large works near Baltimore, to which fuel must be carried over 200 miles and ores brought from Cuba, and also doubt the wisdom of the additions to the iron and steel works at and near Pittsburgh and Chicago. In short, we must assume that those most intimately associated with the pig iron industry have given no thought to its future.

Mr. Atkinson apparently treats of the future solely in the light of the past, without making due allowance for possible and probable advances in mining, preparing and transporting fuel, ores, etc., in modifying present practice or processes, or in utilizing waste materials. The next quarter of a century may show improvements which would surprise us as much as the output of some of our mines or furnaces or the

present use of compressed air, electric light and gaseous fuel would have done twenty-five years ago.

The iron industries of Pennsylvania are here to stay, the ores of New York and of the Lake Superior region will continue to be in great demand, the South and the West will add to their industries; Canada, too, will develop her resources, iron production and manufacture will extend beyond the Continental divide and follow the tide of population rather then congregate in a limited area of mineral development. In this, the localities indicated by Mr. Atkinson will share, and possibly share liberally, but allowing for a considerable export trade, it is probable that the future situs of iron production of the United States will be considerably removed from the point indicated and that of the world still further from the highest peak of the Great Smoky Mountains.

FUEL GAS: ITS PRODUCTION AND DISTRIBUTION.

By Arthur Kitson.

[*A paper read before the Franklin Institute, February 18, 1891.*]

Fuel gas is not quite so recent a discovery as many people suppose. Half a century ago, M. Ebelmen described, in a paper read before the French Academy of Sciences, a method for utilizing charcoal *débris*, coal slack, and other carbonaceous refuse, by converting them into the form of gaseous fuel, which was conveyed to suitable furnaces, and there consumed. This process was operated with considerable success at the iron forges of Audincourt. Ebelmen's method formed the basis of nearly all the fuel gas systems that have since been produced, and consisted in the partial combustion of carbon by forcing a limited supply of air or a mixture of air and steam into a furnace containing the solid fuel in a state of combustion. The gaseous products resulting from the gasification of charcoal by a blast of hot air consisted of—

		By Volume.	
Combustible, . . .	Carbonic Oxide (CO)	= 33·3	36·1 per cent.
	Hydrogen (H)	= 2·8	
Non-combustible, .	Nitrogen (N)	= 63·4	63·9 per cent.
	Carbonic Acid (CO_2)	= 0·5	
		100·00	

and with a mixture of air and steam the products were—

		Percentage.	
Combustible, ...	CO	= 27·2	41·2 per cent.
	H	= 14·0	
Non-combustible, ...	N	= 53·3	58·8 per cent.
	CO_2	= 5·5	
		100·00	

Twenty years later the Siemens regenerative furnace was introduced, and the startling results achieved by its inventor in metallurgical work rapidly opened a wide field for the use of fuel gas in the iron and steel industries. It was demonstrated that seven hundredweight of coal would do the same work that had hitherto been performed with a consumption of at least two tons of coke in heating one ton of iron to welding heat; and twelve hundredweight of coal replaced three tons in melting one ton of steel by means of this gas furnace. The success of fuel gas for metallurgical work was at once assured.

Until the supply of natural gas in Pittsburgh had created a demand among domestic consumers for this desirable addition to modern household conveniences, there had been scarcely any attempt to provide private dwellings with any other than illuminating gas. It is true that some attempt was made in Germany to introduce a heating gas, and that as long ago as 1862, a company was formed in Birmingham, England, to supply that city with fuel gas at a cost of sixpence per 1,000 cubic feet. This bill was actually presented to Parliament, but thrown out in Committee of the House of Lords, because their lordships thought that if the scheme was as good as represented by its promoters existing gas companies would gladly engage therein. It is needless to say that the existing gas companies, already possessing the lighting monopoly of cities, did not care to

undertake any experiments nor embark in fresh schemes, and it was reserved for an individual twenty-five years later to put the first fuel gas plant in operation for domestic purposes. In this country progress has been more rapid, owing, undoubtedly, to the presence of natural gas. The great boon that the discovery and use of this gas has been to certain portions of the West, resulting in the foundation and growth of large and prosperous towns—a discovery that has brought health and happiness to thousands, besides enriching those districts where it exists to the extent of millions of dollars, has excited a demand for an artificial substitute where natural gas does not exist that must sooner or later be supplied. Moreover, the long-predicted exhaustion of natural gas in those regions where lately it was most abundant seems nearing realization, as foreshadowed by the recent action of the Pittsburgh companies in cutting off all supplies for industrial uses and confining themselves to domestic consumers. Such districts cannot well go back to their old habit of burning coal direct. A substitute for natural gas is inevitable.

The distinction that is made between fuel gas and illuminating gas arises chiefly from the difference in cost. Illuminating gas makes an excellent fuel gas, providing it can be sold at a price sufficiently low to allow of its use for fuel. In thousands of instances, both coal gas and carburetted water gas are used in cooking and heating stoves, but their uses as fuel are limited, owing to the cost of such heat. Fuel gas necessarily means cheap gas, and in order to take the place of solid fuel, it should not exceed the cost of coal at the place of consumption. Now, since the combustible gases generated from coal, whether by the process of distillation—as in the ordinary coal gas system—or by the conversion of the carbon into carbon monoxide, with the addition of hydrogen from decomposed steam—as in the water gas system—contain less energy than that from which the gases are obtained, it would appear, at first sight, impossible to replace coal by its gases, economically speaking; but when we reflect that out of possibly 29,000,000 units of potential heat contained in a ton of coal, we

derive, in ordinary domestic uses, scarcely perhaps 5,000,000; whereas from thirty to fifty per cent. of the total heat of combustion of gas is readily available, it becomes evident that we can afford a good margin of loss for the conversion of coal into gas, and still achieve better results than with the coal itself. The saving of space occupied for coal storage, and all the expense and trouble incident to handling coal and removing ashes, to say nothing of the cleanliness and healthfulness, are points of sufficient advantage to give to fuel gas a superiority, if even the economy were no greater than with coal. I do not mean to say that it is cheaper in all cases to convert coal into gas, and burn the gas, than to use the coal direct. There are uses to which coal burned directly is the cheaper system. Such, I believe, is at present the case with the modern steam boilers, where combustion is, in able hands, nearly perfect, and the products escape at a temperature not exceeding 500° F.

In order to ascertain the cost of a gas, we must know, first, its composition; second, the purpose for which it is to be used; and, lastly, the price per unit of volume. Its composition gives us both its heating value and flame temperature. Having given the use to which it is to be applied, we may judge of the quantity we must consume to produce a given effect. Finally, its price per 1,000 cubic feet enables us to figure the cost at which we can do our work.

It may be useful at this point to call attention to the distinction between the calorific value of a gas and its calorific intensity. There is a great deal of misapprehension prevalent on this subject. If we wish to select a gas for heating a substance to incandescence, a Welsbach burner, or Fahnehjelm comb, for instance, we need a flame of high calorific intensity, and should choose uncarburetted water gas. If, on the other hand, we wish to boil water, we should choose natural gas, and next to that coal gas. Of course, this supposes no difference in their cost. The calorific value of a gas is the sum total of the heat units contained in its combustible constituents, irrespective of the diluents associated therewith, *i. e.*, heat units per unit of volume

Calorific intensity is dependent, not alone on the thermal units contained in the gas, but varies inversely with the weight of the resultant products of combustion of the gas multiplied into their specific heat.

Of all artificial substitutes for natural gas, that commonly known as water gas is by far the most popular, and claims the greatest number of advocates.

Water gas is made, as most of you are aware, by forcing steam through a deep body of incandescent coal or coke. This action is alternated with that of blasting air through the fuel to regain the necessary temperature of combustion preparatory to again driving in steam.

The steam is decomposed in presence of the incandescent carbon, forming carbon monoxide, the hydrogen of the steam remaining free. These two gases, H and CO, are given off in about equal quantities, and burn with a beautiful pale blue flame. The chemical transformation is conveniently represented by the equation $C + H_2O = CO + H_2$. This, however, is not the precise manner in which the transformations occur. Carbonic acid gas is first formed and is converted into carbon monoxide in presence of more carbon. It is exactly represented thus: $4\ H_2O + 4\ C = 8\ H + 2\ CO_2 + 2\ C = 8\ H + 4\ CO$.

Coal gas, that made by the retort system, has also its advocates as a fuel gas, but hitherto there has been no practical demonstration of its production at a price calculated to ensure its use as a fuel to any great extent. The returns from its manufacture and supply are based largely upon the sale of the bye-products, coke, tar, naphthaline, ammoniacal liquor, etc., and the profits are, therefore, dependent upon fluctuating markets for these products, as well as the price of the gas. This system pertains, therefore, rather more to what is commonly known as the chemical, than to the gas industry.

It has been proposed to convert the bye-products, coke and tar, into gas and mix with the distilled gases; but this virtually brings the system within the class of water gas systems, since the solid fuel, coke, would be treated by the ordinary water gas process. Moreover, it is quite possible

to carry on the process of distillation, and the water gas process in one and the same generator, and so avoid the extra labor and expense which the retort system entails.

WATER GAS—SEMI-WATER GAS—PRODUCER GAS.

Let us now investigate the methods described for gasifying coal for fuel purposes, in order to ascertain in what way we are likely to achieve the best results. We may conveniently divide them into the three classes, viz: water gas, semi-water gas and producer gas. The first is known as the alternate system, in contradistinction to the last two methods which are continuous.

Taking the first method described by Ebelmen of gasifying carbon, viz: forcing a blast of air through a deep bed of the ignited fuel (producer gas), you will see by the table above given we get only about thirty-five per cent. of combustible gases. If we could eliminate the nitrogen from the atmosphere by a cheap and simple process, and supply oxygen alone and in the requisite quantity to convert all of the carbon into carbonic oxide, we should get from one ton of anthracite of 2,240 pounds, 4,666 pounds, or nearly 60,000 cubic feet of this gas, containing 20,200,000 heat units. The coal itself would possess almost one-third more heat units than this, *i. e.*, 29,000,000, if we allow 240 pounds of the ton as ash. Apparently, there is here a decided loss in converting coal into gas. The loss is, of course, due to the partial combustion which takes place when one atom of oxygen unites with one of carbon, carbonic oxide being the product. In other words, if we convert the carbon at once to its final product, carbonic acid (CO_2) from one pound of carbon so consumed, 14,500 heat units are evolved; whereas, if we turn the carbon first into carbonic oxide (CO), we evolve from the same pound of carbon 4,400 heat units, obtaining 233 pounds of CO; and this, when burned, evolves only 10,092 units, so that the 4,400 units appear to be lost.

What becomes of this heat we call lost? It is generated in the furnace, and whilst some of it is radiated through the sides, most of it is carried off by the gas, which leaves the furnace at a high temperature. If, therefore, we use the

gas in its heated condition as it is generated, we shall lose, approximately, only that quantity lost in the furnace itself. We should obtain the 20,000,000 heat units from the actual combustion of the gas, and probably 7,000,000 units more of sensible heat. Now, the effect of the nitrogen—the presence of which we cannot avoid, if we use air—is, not to lessen the total quantity of the carbonic oxide producible, but to lower the temperature of the furnace. The weight and volume of gaseous products being greatly increased, the heat is spent over a larger volume, and the temperature is necessarily reduced. Of course, a given volume is less combustible than when the nitrogen is absent. In this case we obtain 170,000 cubic feet of gaseous products, 110,000 feet of which is inert nitrogen. What would be the temperatures of the furnace where the nitrogen is present and where absent? In the one case, the furnace heat would be

$$\frac{2{,}000 \times 4{,}400}{4{,}666 \times \cdot 2479} = 7{,}600^\circ \text{ F.}$$

In the other,

$$\frac{2{,}000 \times 4{,}400}{(4{,}666 \times \cdot 2479) + (8{,}664 \times \cdot 244)} = 2{,}685^\circ \text{ F.}$$

By "furnace heat" we mean the average temperature existing in the furnace. In practice, we have really a gradually descending degree of temperature from the zone of combustion to the zone of distillation—where the gases leave the furnace. The zone of combustion exists where the air is supplied to the fuel. In this region active combustion ensues, and the carbon is converted into carbonic acid gas, per saltum. In passing through the superincumbent coal, the carbonic acid gas gives off part of its sensible heat to the coal, and at the same time undergoes a transformation by losing an atom of oxygen, which unites with the free carbon, and is thus converted into carbonic oxide (expressed by the equation $CO_2 + C = 2CO$). That portion of the furnace in which this chemical transformation occurs we term the zone of carbonization. This change entails a further loss of heat.

In passing out at the top of the furnace, the gas imparts a

further quantity of sensible heat to the top layers of fresh unconsumed coal, and carries off the moisture in the form of steam. There is, therefore, a gradually diminishing furnace heat from the zone of combustion, (say) 2,500° to 3,000° F. down to probably from 1,000° to 1,500° at the take-off pipe.

Now, if the gas has to be stored for any length of time, or conveyed long distances through cold pipes, a very severe loss is necessarily entailed. For instance, in burning the gas produced from a ton of coal, at atmospheric temperature, we should lose an amount of heat equal to from 4,000,000 to 7,000,000 heat units. This would prove a serious loss, and in order to avail ourselves of a portion of this thermic capital, we must burn the gas as it issues from the gas furnace without permitting it to cool.

As most of you are aware, the feature of Siemens regenerative furnace consists in the utilization of this sensible heat. We are now in a position to understand the advantage of using steam mixed with the air and see how it is made available. Steam enables us to lower the furnace temperature, and consequently reduce the sensible heat of the gases, at the same time conserving the thermal energy for future use. By injecting a mixture of steam and air, we require less air than where it is used alone, since the steam provides a certain quantity of the oxygen necessary to convert the carbon into carbon monoxide. The air maintains the furnace temperature essential for decomposing the steam in the presence of the red-hot coal; the oxygen of the steam unites with the coal to form carbon monoxide (CO), and the hydrogen remains free. You will, therefore, see the enormous advantage the use of steam thus affords. Instead of free nitrogen, we get free hydrogen, which is not only a highly heating and combustible gas, but exceedingly light, and confers low specific gravity to the gaseous products with which it is associated—a feature of considerable advantage where the gases have to be carried some distance before burning. Of course, the use of steam entails a consumption of the heat energy of the furnace, and it becomes a rather nice point to so proportion the steam and air that

the fuel can maintain sufficient heat to carry on the chemical transformation of the steam to combustible gases, and reduce, at the same time, the quantity of air to a minimum. The less the amount of air used, the less the proportion of inert nitrogen in our fuel gas—a point to be aimed at; and the greater the proportion of steam the greater will be the heating power of our gas, providing always the requisite furnace heat be maintained to decompose the steam effectively.

If we ascertain the heat generated in the furnace, and that expended in effecting the chemical transformation of a given weight of steam into combustible gases, the furnace temperature can be known, and this will guide us in determining what amount of steam may be used with success.

Having given the following data, let us calculate the results:

Eight hundred pounds steam supplied from a boiler at 300° F.; 2,240 pounds anthracite or coke, containing 240 pounds ash; 10,013 pounds of air. We will allow for a loss of twenty per cent. of steam that will, in all probability, escape decomposition in the furnace; also, ten per cent. of carbon burned to CO_2.

HEAT PRODUCTION.

	B.T.U.
1,800 pounds of carbon burned to CO = 1,800 × 4,400 =	7,920,000
200 pounds of carbon burned to CO_2 = 200 × 14,500 =	2,900,000
Heat carried in by steam, 800 × 300° × ·475 . . . . . =	114,000
	10,934,000

HEAT EXPENDED.

Allow twenty per cent. of steam as wasted in escaping through furnace without undergoing decomposition:

	B.T.U.
160 pounds heated from 300° F. to (say) 1,300° F.	
160 × 1,000 × ·475 . . . . . =	76,000
Conversion of 640 pounds of steam at 300° F.	
$\frac{8}{10}$ × 53,900 . . . . . =	3,832,290
Allow ten per cent. loss in furnace by radiation, etc, . =	1,093,400
	5,001,690

Then, 10,934,000 — 5,001,690 = 5,932,310 heat units contained in the furnace.

Our furnace heat is determined as follows:

CO_2,	= 732 pounds × 0·2164 =		158·405
CO,	= 4,194 pounds × 0·248 =		1,040·212
N,	= 7,660 pounds × 0·244 =		1,869·040
H,	= 71·11 pounds × 3·4046 =		241·774
	12,657·11		3,309·431

and

$$\frac{3,309{\cdot}431}{12,657{\cdot}11} = {\cdot}261$$

being the average specific heat; and

$$\frac{5,932,310}{12,657{\cdot}11 \times {\cdot}261} = 1,800^\circ \text{ F.}$$

being the average furnace heat.

The proportion of gases by volume will be as follows:

H,	12,700	Combustible, about 39 per cent.
CO,	53,700	
CO_2,	6,000	Non-combustible, 61 per cent.
N,	97,900	
	170,300 cubic feet.	

Now, this temperature is much higher than is necessary for decomposing steam, and shows that our proportion of steam to air is too small for economical work. We may, therefore, increase the weight of steam with advantage.

Let us increase the weight of steam one-third, making it 1,200 pounds. We have then—

	Pounds.
Coal,	2,240
Carbon,	2,000
Steam,	1,200
Air,	8,810

In these tables I have not allowed for an excess of air, which is, of course, essential in practice, and which will somewhat modify the results theoretically obtained.

HEAT PRODUCED.

	B.T.U.
1,800 pounds (C to CO) = 1,800 × 4,400	= 7,920,000
200 pounds (C to CO_2) = 200 × 14,500	= 2,900,000
Heat carried in by steam 1,200 × 300° × ·475	= 171,000
	10,991,000

HEAT EXPENDED.

	B.T.U.
20 per cent. escaped steam, 240° × 800 pounds × ·485 =	91,200
Conversion of 960 pounds steam, $\frac{960}{8}$ × 53,900 . . . =	5,748,900
10 per cent. loss by radiation . . . . . =	1,099,100
	6,939,200

Then, 10,991,000 — 6,939,200 = 4,051,800 heat units in the furnace.

Then to ascertain the furnace temperature:

CO_2 =	733	pounds × 0·2164 . . . . . =	158·621
CO =	4,194	pounds × 0·2479 . . . . . =	1,040·212
N =	6,740	pounds × 0·244 . . . . . =	1,644·560
H =	106·66	pounds × 3·4046 . . . . . =	362·644
	11,773·66		3,206·037

Then

$$\frac{3,206{\cdot}037}{11,773{\cdot}66} = {\cdot}272$$

the average specific heat, and

$$\frac{4,051,800}{11,744 \times {\cdot}2723} = 1,280^\circ \text{ F.}$$

being the average furnace heat.

The amounts of the gaseous products by volume in this case are:

		Cubic Feet.	
Combustible, ...	H, ...	= 19,000	44 per cent.
	CO	= 53,700	
Non-combustible, . . .	CO_2, ...	= 6,000	56 per cent.
	N, ...	= 85,800	
		164,500	

The total heat units are as follows:

	B.T.U.
H = 106·66 pounds × 62,000 . . . . . =	6,612,920
CO = 4,194 pounds × 4,325 . . . . . =	18,139,050
	24,751,970

and

$$\frac{24,751,970}{164,500} = 151 \text{ B.H.U.}$$

per cubic foot, which is nearly one-half the value of uncarburetted water gas.

Are these results the best attainable? I think not. In a properly constructed furnace we ought to be able to obtain and maintain fifty per cent. of combustible gases from the total products. With care we can work at a lower temperature than that last obtained, because experience shows that the gases do not leave at furnace heat.

Supposing they leave at 800° F., then the furnace temperature is increased:

$$\frac{480 \times \cdot 272}{\cdot 22} = 589° \text{ F.}$$

the temperature becoming 1,869° F.

A large percentage of the heat ordinarily lost through the brickwork, as well as the sensible heat of the products themselves, may be utilized by heating the steam and air before they enter the furnace.

Of course, these calculations are based on theoretically perfect combustion, and no excess of air has been allowed.

Under the best conditions it is possible to decompose 1,500 pounds of steam to every ton of coal, providing the steam is furnished from an independent source, and to obtain approximately the following results:

		Weight. Pounds.	*Volume.*	*Heat Units.*
Combustible,	Hydrogen,	1,666	29,800	10,333,292
	Carbonic oxide,	4,194	53,700	18,139,050
Non-combustible,	Nitrogen,	5,179	65,500	—
	Carbonic acid,	733	6,000	—
		10,272	155,000	28,472,342

This equals nearly fifty-four per cent. combustible products and gives 183 heat units to the cubic foot. Can this quality be generated continuously? Experience shows that it can, providing the steam and air are supplied at a sufficiently high temperature. With steam furnished from a separate boiler, at (say) 500° F., no difficulty will be found in producing this quality of gas.

There is still the fuel requisite for supplying the steam to be calculated and allowed for in these results. To produce 1,500 pounds of steam from water at atmospheric temperature and raise it to 500° would necessitate a consump-

tion of from one-eighth to one-quarter ton of coal; so that our results are reduced to 130,000 cubic feet of gas, containing 183 heat units to the foot, or 23,500,000 heat units to the ton of coal.

The question naturally arises whether it is possible to generate the steam in the same furnace and still maintain the quality of gas.

To do this we have only the waste heat of the furnace, *i. e.*, the sensible heat carried off by the gaseous products, and that radiated through the brickwork, to work with, since we cannot lower the temperature of the furnace without seriously affecting the quality of the gas. As shown, we need 2,500,000 B. T. U.

Suppose the gases leave the generator at 500° F. above the atmosphere. There are 10,250 pounds × 600° × ·272 = 1,660,000 B. T. U. carried away by the gaseous products from one ton of fuel, and allowing ten per cent. loss for radiation, etc., 1,090,000, making a total of about 2,750,000 heat units.

If it were practicable to utilize entirely this waste heat in producing and superheating the steam, the perfection of the gasification of coal would be reached, for there would be contained in the combustion of the gases ninety-five per cent. of the heat units contained in the coal itself. By placing a superheater in the take-off pipe, and a superheating coil in the brickwork, a considerable amount of this waste heat becomes available.

Allowing for all contingencies, I believe it is possible to obtain from 2,240 pounds of anthracite from 150,000 to 160,000 cubic feet of semi-water gas, averaging 165 heat units to the foot, which will contain 25,000,000 units of potential heat, or about eighty-three per cent. of the heat energy of the coal itself.

This system possesses, in my judgment, the best solution of the fuel gas question. The cost of its production is trifling, and the labor attached to its manufacture (usually a considerable element in the cost of gas) very slight.

With coal at $3 per ton, its cost of production should not exceed two and one-half cents per 1,000 cubic feet. In other

words, we ought to obtain 1,000,000 heat units at a cost of fifteen cents. At the present price of Philadelphia city gas this same quantity of heat costs $2.30!!

The objections that are urged against the use of gas of this quality are: (1) That the presence of so much inert matter necessitates the use of larger pipes, and (2) that combustion is maintained with difficulty. The first of these objections only applies where it is absolutely necessary to use the pipes already existing and hitherto used for illuminating gas. If new pipes have to be laid it is not so great an undertaking to lay a nine-inch pipe, instead of a six-inch, for instance, and should not prove a serious obstacle.

But the same objection would hold good as against water gas. Water gas contains only one-third the heating value of natural gas and one-half that of coal gas; and if a certain sized pipe were just sufficient to carry natural or coal gas, it would be too small for water gas unless the pressure were considerably increased, and this would necessitate better laid mains and better joints than we are now accustomed to.

When gas becomes generally used for fuel, no such sizes of mains as those now used for the supply of illuminating gas will furnish anything like the demand.

Moreover, in the method of distribution that I will presently describe, this objection vanishes.

The question becomes a mere arithmetical problem: Does the interest on the investment required to provide larger mains equal, exceed, or is it less than the value of the extra heat units supplied?

This is a simple problem and its solution is an answer to this question. It is merely a question of dollars and cents.

The other objection urged is that that there is difficulty in maintaining combustion. This objection is confined almost entirely to the gas known as producer gas, that made in blasting the furnace in the water gas process, in which the combustible products do not exceed thirty-five per cent. With the gas I have described, combustion is readily maintained, especially when it is heated prior to ignition, a condition easily obtained for all ordinary purposes.

Water gas, made by what is known as the alternate method, consisting in alternating the steam and air blast, will furnish under the best conditions not more than 40,000 cubic feet of gas, containing 300 heat units per foot, a total of 12,000,000 to the ton of coal. It is composed of carbon monoxide and hydrogen, almost entirely. The producer gas—that given off in blasting the furnace with air—is of too little heating value to convey long distances, and must be burned in large quantities to be effective. It is advantageous to burn this under the boilers for furnishing steam.

The thermal intensity of water gas is very high, whilst its calorific value is less than half that of coal gas. Its success as a fuel depends solely on one point, the cost of distribution. It can be produced cheaply enough to warrant its introduction, but, unfortunately, the expense incurred in getting it from the holder to the consumer is generally greater than that of manufacturing and putting it into the holder. It is already in use for fuel in several cities, and is sold, I understand, at forty and fifty cents per 1,000 feet. Fifty cents is too much. Coal gas at $1.25—the price charged in New York City—is just as cheap for ordinary domestic purposes. To compete successfully with coal, water gas containing 300 heat units to the foot should be sold at twenty cents per 1,000, at which price there will be no difficulty in selling all that a company can produce in every city, except where natural gas is already supplied.

To recapitulate: Of the three methods for converting coal into gas for fuel, viz: by natural or forced draught without steam, by forced draught with steam, and by steam and air alternately—resulting in the generation of producer gas, semi-water gas and water gas, respectively—semi-water gas contains eighty to eighty-five per cent. of the heating value of coal, and is the cheapest gas if supplied within a reasonable distance from the place of production.

Producer gas must be burned hot as it issues from the producer, to be advantageous. Water gas contains only about two-fifths of the heating value of the coal from which it is produced, and is, *per se*, the most expensive of the three systems.

The accompanying diagram (*Fig. 1*) represents these three gases proportionately by volume, and with their constituents.

FIG. 1.

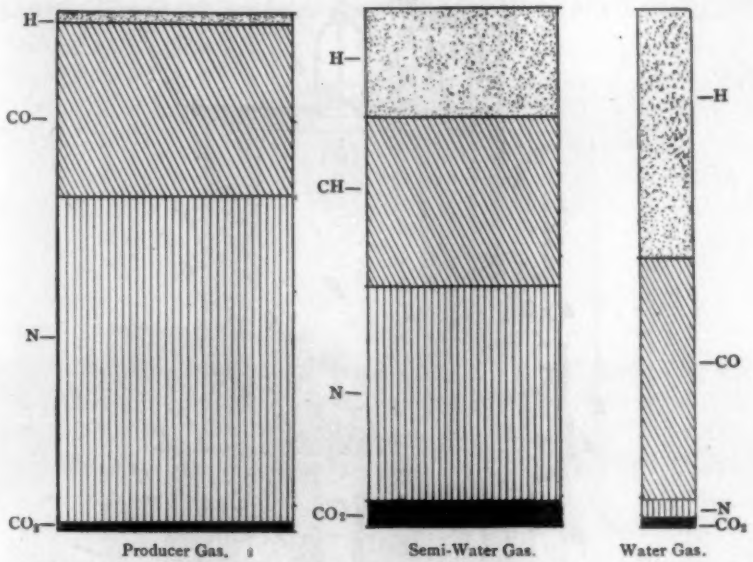

Diagram showing comparative amounts of the various constituents of producer gas, semi-water gas and water gas from a ton of anthracite.

Not the least of the advantages which semi-water gas, or "steam-jet" producer gas, as it is sometimes called, possesses over water or coal gas, is the ease and simplicity of its production. It can be made in a furnace not much larger than some that are in use for heating dwellings, it requires no storage, is automatic in its production, and can be made in quantities varying from 500 cubic feet to an indefinite quantity per hour.

DESCRIPTION OF KITSON'S GAS PRODUCER.

In compliance with the request with which your Secretary honored me, I will briefly describe the apparatus I have designed for the manufacture of semi-water gas, and am now using in connection with the Körting gas engine for the production of power. This furnace has been in use for some time driving the gas engine, which sup-

plies power to a dynamo, and this in turn charges a storage battery. The battery furnishes current for a

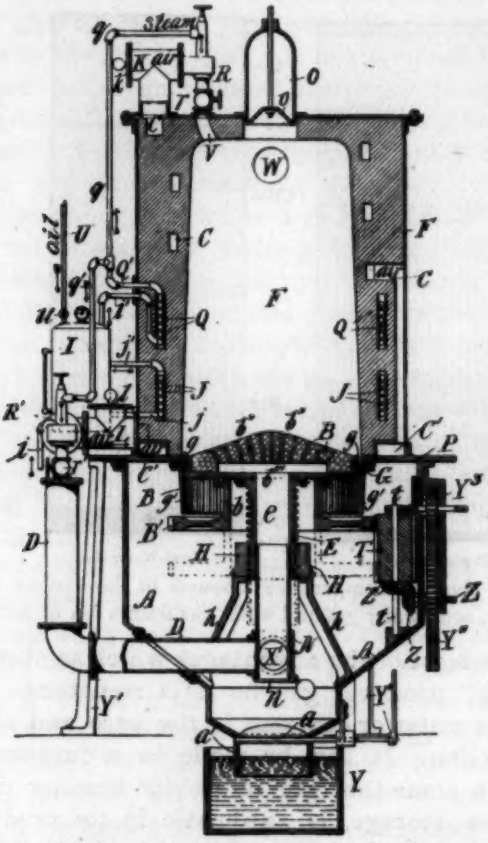

FIG. 2.—Sectional view of the Kitson Gas Generator.

Explanatory.—*A*, ash pit. *B*, fire-brick hearth or grate. *C*, air passage-ways for heating air supplied to injectors. *D*, injector pipes leading to centre of grate. *E* and *H*, screw and hub for giving grate the rotary and up-and-down motion. *F*, furnace. *G*, vertical grate bars. *I*, steam boiler. *J*, hot-water coils connecting with boiler. *Q*, steam superheating coils, communicating with boiler. *N*, dust valve. *R*, injectors. *O*, hopper to supply coal to furnace. *T*, *Y*², *Z*, mechanism for rotating the grate. *X'*, *W*, gas take-off pipes. *Y*, water seal. *a*, butterfly valve for dumping ashes.

number of incandescent lamps, and occasionally for a small electric motor. The producer is represented in the engrav-

ings (*Figs. 2* and *3*). It occupies about ten square feet of floor space, and stands eight feet from the floor to the top of the feed hopper. This will furnish 1,500 cubic feet of gas per hour. The machine consists of a cylindrical shell of boiler

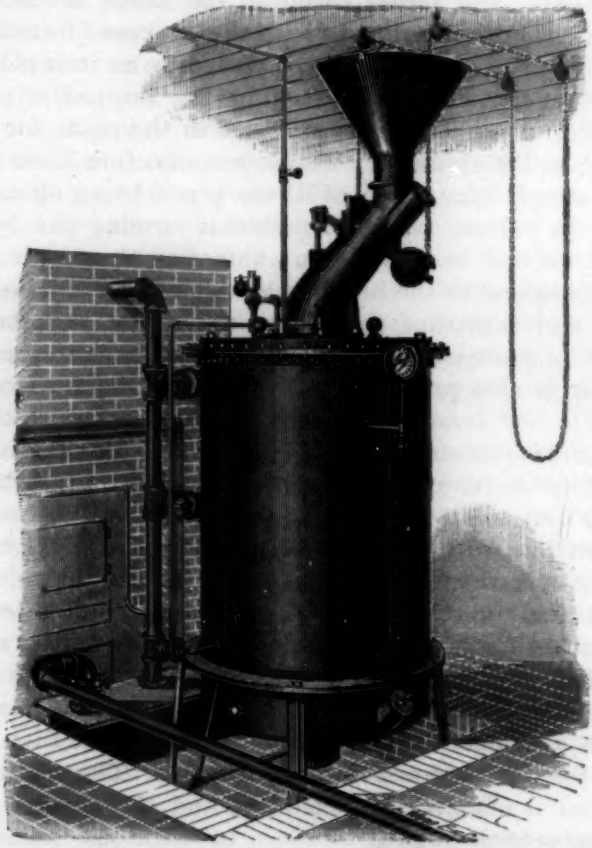

FIG. 3.—The Kitson Gas Generator, exterior view.

iron lined with fire-brick. The internal diameter of the brickwork is 21 inches, and the height from the grate to the top of the furnace is 3 feet 6 inches. The grate is connected on one side with a steam and air injector; on the other, with the gas supply pipe (which runs to the place of consumption),

and is surrounded by a cast-iron box securely attached to the cylindrical shell, forming the ash pit. The whole machine is supported on four cast-iron legs.

The ash box terminates in a mouth-piece, which is opened and closed with a valve operated by a lever from the outside, and serves to dump the ashes, whenever desirable, without interfering with the process of making the gas. The top of the furnace is closed by an iron plate, and upon this the hopper for feeding the furnace is securely fastened. An opening is provided in the plate for a pipe leading to the chimney. Another connection leads also to a gas supply pipe, each of these pipes being opened and closed by valves. A small reservoir forming the boiler is placed on one side and communicating therewith are two coils contained in the brickwork. The lower coil heats the water and furnishes steam, the upper coil superheats it. Water is pumped into the boiler from time to time. An injector is also provided at the top of the furnace. Air channels are arranged spirally in the brickwork, through which air is drawn by the injectors. The air thus becomes heated before mixing with the steam, which must be thoroughly dry. The walls of the furnace, it will be seen, are inclined inwardly towards the top, and outwardly towards the bottom, thus throwing the entire weight and body of the fuel on the grate. The grate is provided with mechanism for giving it a rotary and up-and-down motion, the effect of which is to break up any clinker that may have adhered to the sides of the furnace to keep the coal in a compact mass, avoiding holes in the fuel and to throw the dust and ash into the ash-pit. The caking with soft coal is effectively broken up, and the steam finds an easy passage through it.

The entire gas plant I have described is simple, cheap in construction, and economical in its working. It can be made small enough to produce 500 cubic feet per hour, which means a consumption of only six or seven pounds of coal. It is easily set up, taken down and removed. There is no danger from fire or explosion, and it requires but ordinary care, as in the case of a common coal furnace.

APPLICATIONS OF FUEL (SEMI-WATER) GAS—POWER.

Let us now consider in what manner we may utilize our gas and ascertain the results obtainable. Commencing with the subject of power: It may astonish the general public, who are accustomed to regard the highly developed steam engine as the perfection of human ingenuity in the transformation of heat into work, to learn that the gas engine, with all its imperfections, is a far more efficient instrument. Although the gas engine is limited in various ways, in capacity and power, and is, mechanically speaking, vastly inferior to the steam engine, its absolute efficiency is at least double that of its rival. The absolute efficiency of the gas engine is twenty per cent. and has in some cases exceeded twenty-two per cent. whilst that of the best steam engine never exceeds half this amount. With illuminating gas a consumption of from twenty-five to thirty cubic feet per hour in any of the standard gas engines will develop one actual horse-power, which is equivalent to a consumption of from 15,000 to 18,000 thermal units.

During the past year I have made a great number of experimental tests of semi-water gas with the Körting gas engines, varying in size from eighteen horse-power down to two horse-power, and found no difficulty with a consumption of eighty-five cubic feet in developing an actual horse-power by brake test. This is equivalent to one and one-fourth pounds of coal per horse-power per hour. For several years a well-known firm in Manchester, England, have supplied their works with power by means of gas producers and gas engines, and claim the cost has not exceeded one and three-fourths pounds of coal per horse-power per hour.

A recent test with an Atkinson engine gave one horse-power with $1\frac{11}{100}$ pounds per hour.

In comparison with the steam engine, these results are startling. Compare, for instance, the efficiency of the best steam plant, comprising furnace, boiler and engine, with gas producer and gas engine. It is hardly fair to make comparisons with very large steam plants, for the simple reason that the largest gas engine does not exceed 100 horse-power.

A fifty horse-power steam plant of the most approved pattern will consume 45,000 thermal units in the production of each horse-power per hour, an efficiency of less than seven per cent. In the largest plants the efficiency will not exceed ten per cent. Now, take the gas plant: We get an efficiency in the gas producer of eighty to eighty-five per cent., and in the gas engine from eighteen to twenty-two per cent., an absolute efficiency of from fourteen and one-half up to nearly nineteen per cent. for the entire plant. Here is a method for the supply of power for which there is an unlimited field, and, notwithstanding the years that have elapsed since attention was first called to the subject, it is entirely unknown to the public generally. Instead of large reservoirs for the supply of steam, we may generate gas as required, converting its potential energy into useful work more economically and more efficiently than has ever been dreamed of by steam engineers. The gas producer and gas engine must eventually supplant steam for all small uses, at least.

My experiments showed me:

(1) That it is decidedly advantageous to clear the cylinder entirely of the exploded products before taking in a fresh charge.

(2) That a higher compression than that ordinarily used with illuminating gas is beneficial.

(3) That sufficient time should be allowed to enable the gas and air to intermingle in the exact proportions for combustion, before ignition.

The presence of a small proportion of the exploded products in the new charge affects this quality of gas much more disastrously than where a richer gas is used. There being already fifty per cent. of non-explosive gas in the charge itself, the addition of a small percentage of so injurious a diluent as carbonic acid gas, injures the explosive force of the charge materially.

The best effects from the use of this gas may, therefore, be expected from engines having a variable piston stroke, such as the Atkinson.

The disadvantages attending the slow combustion of

carbonic oxide gas (especially when this gas is accompanied by much nitrogen), is, to a great extent, remedied by high compression. High compression also increases the capacity of a given-sized engine, a decided advantage where semi-water gas is used.

The outlook for the gas producer and gas engine is very encouraging, and bids fair to outrival the steam boiler and engine. Not only is it more economical in the conversion of potential heat units into work, but there is less labor involved and less danger.

The results I have mentioned may at first sight seem startling, especially to those accustomed to the use of small steam plants, where the consumption of coal varies all the way from four to ten pounds of coal per horse-power. So accustomed have we become in our crude utilization of natural forces, to throw away more than we use, that we are apt to lose sight of the proportion and magnitude of such waste.

Every factory and household chimney, every locomotive stack, every ash pit and dust bin testify to the frightful extravagance in our modern and much vaunted methods of utilizing fuel. When we reflect that in every pound of coal lies hidden a force which, if wholly utilized, would furnish four or five horse-power, whilst at present we employ at least ten pounds, and often forty, to accomplish the same results; that in our highly efficient gas motor we consume five volumes to obtain the energy contained in one, some idea of the present wasteful methods of producing power may be realized.

The prediction, therefore, that the gas engine and gas producer will shortly furnish power with one pound of coal per actual horse-power per hour, is only incredible to those who regard present achievements as the summit of human attainment.

LIGHT.

This question of cheap power brings us directly to another—the production of light. The great obstacle the electric light encounters when competing with gas is the cost of power. Here, it seems to me, is a solution of the problem.

Taking an incandescent electric plant, capable of furnishing ten lamps of sixteen candle-power to the actual horse-power, the cost of coal would be less than one-quarter cent per hour. This would permit the use of storage batteries and allow a margin for loss in discharging. The gas is also available in connection with the incandescent gas lamps, such as the Welsbach and Lungren. I have used the former with success. The Kitson water gas lamp, in which the gas is carburetted by the vapor of naphthaline, produces a very beautiful light with semi-water gas.

HEAT.

For heating purposes its uses are almost endless. With properly constructed burners, gas cooking and heating stoves are available for domestic purposes, whilst for industrial work its different uses are legion—brick burning, lime burning, soldering pots, singeing yarns, roasting and smelting furnaces, cupolas, etc., and, in fact, wherever artificial heat is required, this gas may be made available in one special way or another.

DISTRIBUTION.

Chief among the items that make the price of gas high to consumers is the cost of distribution, and in large cities it is certainly attended with the greatest conceivable annoyance and expense. The tearing up of roadways, the laying, relaying and repairing of pipes, the loss from leakage, the suits for damages, the conflicts with City Councils, with surveyors, with street-car companies, and with property owners, serve to make the lot of a gas company at times anything but a happy one. These expenditures have to be met, and serve to make the price of gas to the consumer wholly out of proportion to its cost of manufacture.

The plan I wish to suggest for supplying fuel gas, in its three departments, as light, heat, and power, is, to bring the place of manufacture and point of consumption as near together as possible, and avoid long distance of delivery. I would let every block of houses contain its own gas works and electric light station. A basement in the centre of a

block would be provided and equipped with several gas generators, gas engines, dynamos and storage batteries. This plant I would erect in a substantial manner, and, where necessary, dig below the basement for several feet. I would put in good foundations and sink the generators considerably below the floor level for convenience in supplying the hoppers with coal. One set of generators I would keep constantly in operation, running gas engines which would operate the dynamos, continually charging the storage batteries to supply the necessary lights. This part of the plant I would operate twenty-four hours a day so as to reduce the size and cost of the plant requisite to do a given amount of work. Another set of generators would furnish gas for heating and cooking. Boilers would be used for supplying steam heat or hot water in the ordinary manner. Pipes would be run from the main tank to each house in the block, and wires connected from the storage batteries in the usual way. It would be necessary to have a small holder under each house, which I would also sink below the floor level in the basement. This holder would regulate any great variation in the supply of gas. Each block would thus be provided with its own plant, and be entirely independent of central stations and city gas companies. Duplicate sets of machines would have to be kept ready in the event of one or more of the others giving out. The advantages to be reaped by this system would be, first, that owing to the short distance which the gas and electric current would have to travel, the cost of supply, as well as the amount of capital invested, would be reduced to a minimum; second, this system avoids at once the overhead wire nuisance and the annoyance of tearing up the streets to alter and change the gas mains; third, consumers would be entirely independent of City Councils and city franchises; they would have simply to consult themselves and their own interests, and deal with their own property; and, lastly, an accident to one gas plant would not interfere with the lighting of a whole district, as is the case under the present system.

By this method of distribution you will see that the objec

tion urged against the carrying of a quantity of inert gas, necessitating very large mains, disappears.

I am about introducing this system into a block of buildings in New York City as an experiment, and shall be happy to give you, at a future time, the results of that experiment.

PROCEEDINGS
OF THE
CHEMICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Stated meeting held Tuesday, November 17, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 17, 1891.

Dr. W. H. WAHL, President, in the chair.

Nominations of officers to serve during the coming year were made, as required by the by-laws.

In the cases of President, Secretary, Treasurer and Conservator, the present incumbents, namely, Dr. Wm. H. Wahl, President and Conservator; Dr. Wm. C. Day, Secretary; Dr. H. W. Jayne, Treasurer, were re-nominated.

Dr. E. F. Smith and Dr. Wm. H. Greene were nominated as Vice-Presidents.

The following nominations for membership in the Section were made, viz: Mr. Geo. W. Whyte, of the Camden Iron Works, Camden, N. J.; Mr. Alfred N. Seal, 417 Locust Street, Philadelphia; Dr. Herbert M. Kaufmann, 1325 Franklin Street, Philadelphia, and Mr. S. W. Young, of Swarthmore College, Pa. These nominations were referred to the Committee on Admissions, by whom they were favorably considered, and the persons named were declared elected.

Letters of resignation from Mr. Everett W. Frazer, at present of New York City, and Mr. A. A. Moore, of the Franklin Sugar Refinery, Philadelphia, were read, and the resignations were accepted.

A letter from Mr. M. Carey Lea was read, transmitting to the Section the gift of a collection of his published papers on allotropic forms of silver and a set of specimens of the various modifications of the element which he had prepared. They were examined with much interest by the members present, and, on motion, the Secretary was directed to write Mr. Lea a letter of thanks, conveying the Section's appreciation of the gift.

A number of bills for subscription to journals and also for postage and expenses incurred in sending out notices, were referred to the Finance Committee; they were indorsed by the committee, and payment was authorized.

Mr. Lee K. Frankel read a paper "The Oxidation of the Metallic

Arsenides by the Electric Current." The paper was listened to with interest, and was referred for publication in the *Journal.*

This was followed by one from Mr. Otto Lüthy, on "Carbonic Acid Determination." Specimens of potash pumice and other materials discussed in the paper were submitted for inspection. The paper was referred for publication, and the author stated that at the next meeting he would present the results of a further prosecution of the investigation.

Adjourned. WM. C. DAY, *Secretary.*

I. THE IODATION OF *p*-BROMOBENZOIC ACID. II. SALTS OF *p*-BROMO-*m*-NITROBENZOIC ACID.

BY OLIVER HOUGH.

[*Read at the stated meeting, held October 20, 1891.*]

It is stated by Weselsky (*Annalen*, **174**, 99) that the method of iodation recommended by him is not applicable in the case of bromobenzene, or benzoic acid. Believing that possibly a different result might be obtained with bromobenzoic acid, in which two hydrogen atoms are replaced by different substituents, the following experiments were made:

(1) Ten grams of *p*-bromobenzoic acid, dissolved in alcohol, were heated with the calculated amounts of iodine and mercuric oxide. The product was heated with an aqueous solution of sodium carbonate, and filtered while hot. Hydrochloric acid was added to the cold solution, and the liberated organic acid converted into its barium salt. Analysis showed it to be the barium salt of *p*-bromobenzoic acid. The iodation had not been effected.

(2) It was suggested that possibly the iodation had really occurred, but that the sodium carbonate had again removed the iodine. To ascertain whether such was really the case, the acid after treatment was digested immediately with barium carbonate. The resulting salt proved to be *p*-bromobenzoate of barium.

(3) A third experiment was equally fruitless. Finally, the *p*-bromo-acid, in alcoholic solution, was heated together with iodine and mercuric oxide, in a sealed tube. The temperature of the oven was 150° C. Iodine was not introduced into the acid even in this way.

II. SALTS OF *p*–BROMO—*m*–NITROBENZOIC ACID (m. p. 199° C).

The known salts of this acid are those of barium, magnesium and silver. The following are new:

The *potassium salt* forms yellow-colored prismatic needles, varying in length from one-half to one inch. One hundred parts of water at 26° C. dissolve 33·44 parts of the salt. The salt is anhydrous.

The *sodium salt* crystallizes in needles. It contains one molecule of water of crystallization; 100 parts of water at 26° C. dissolve 16·01 parts of the salt.

The *ammonium salt* separates from aqueous solutions in anhydrous needles; 100 parts of water at 26° dissolve 12·22 parts of the salt.

The *strontium salt* consists of minute white needles. It contains three and one-half molecules of water of crystallization. Found 14·88 per cent. Sr instead of 15·10 per cent.; 100 parts of water at 26° dissolve 0·88 parts of the salt.

The *calcium salt* consists of white needles. The air-dried salt lost, when carefully heated in an air-bath at 160°, 30·25 per cent. of water, corresponding to thirteen molecules. Found 7·45 per cent. Ca instead of 7·54 per cent.; 100 parts of water at 26° dissolve 1·09 parts of the salt.

The *zinc salt* crystallizes in white needles; 100 parts of water at 24° C. dissolve 0·70 parts of the salt. The addition of zinc chloride to a solution of potassium nitrobromobenzoate, produced a white precipitate which crystallized from hot water in round, yellow-colored masses. Under the microscope these appeared to consist of bundles of little plates. An analysis of the salt showed it to be the basic zinc salt. It contains three molecules of water. Found zinc = 20·24 per cent. instead of 19·87 per cent.

The *mercury salt* is anhydrous and white in color; 100 parts of water at 26° dissolve 0·96 parts of the salt. Found Hg = 44·04 per cent. instead of 44·90 per cent.

The *nickel salt* crystallizes in light green colored crusts; 100 parts of water at 26° dissolve 1·47 parts of the salt. It contains two and one-half molecules of water.

The *cobalt salt* consists of pink needles. It contains three molecules of water; 100 parts of water at 26° C. dis-

solve 1·05 parts of the salt. Found 11·53 per cent. Co instead of 10·74 required.

I carried out the above work in the laboratory of Dr. Edgar F. Smith, University of Pennsylvania.

THE OXIDATION OF METALLIC ARSENIDES BY THE ELECTRIC CURRENT.

BY LEE K. FRANKEL.

[*A paper read at the meeting, November 17, 1891.*]

The decomposition of minerals and their subsequent oxidation by means of the electric current is a product of very recent origin. By reference to the literature of the subject, it will be found that the first attempt in this direction was made by Dr. Smith, in a paper published in the *Proceedings of the Chemical Section of the Franklin Institute*, vol. i, p. 52, in which the author has successfully completed the decomposition of chalcopyrite and gives the results of some preliminary investigation on chromite.

In a later and more exhaustive paper in the same journal, Dr. Smith has published his researches on the decomposition of other sulphides, and has proven conclusively that oxidation by the electric current gives results as quantitatively correct as those obtained by any wet or fusion method. In a still later paper by the same author (*American Chemical Journal*, vol. 13, No. 6), experiments on various kinds of chromite, indicate that the decomposition of this mineral is complete, if the conditions prescribed are closely followed. At present this completes the literature of the subject, and judging from the success so far obtained, it was deemed advisable to attempt the oxidation of the metallic arsenides, with the hope that the result would be similarly fruitful. These results and the methods used for obtaining them will be found appended below.

The apparatus used for this purpose was the same as that described by Dr. Smith in the *Proceedings of the Chemical Section of the Franklin Institute*, vol. ii, p. 53, and the method of using it was also substantially the same. The

current generated from four storage cells of the Julien type, was passed through the resistance frame, then through a Kohlrausch ampèremeter, and lastly up through the nickel crucible, the latter being in all cases the positive pole. As for the oxidations, the time required, the strength of current, etc., differed in each mineral respectively. For this reason no general plan can be prescribed, but the details of the work will be found for each mineral, under its respective heading.

Gersdorfite (*Ni.Fe.*),*As.S.*—The sample used for the decomposition came from Shladming. The method of procedure was as follows: In a nickel crucible 1¼ inches high and 1⅜ inches wide, 25–30 grams of solid caustic potash were placed. The contents of the crucible were heated until fusion took place, and the gersdorfite then carefully added. A current registering one ampère was passed through the mass for twenty minutes, the crucible being the anode. Towards the end of the operation, the current was reversed for three minutes to remove any particles of mineral that might have been enclosed in the metal dedosited on the cathode. After breaking the current, the crucible was allowed to cool, then thoroughly disintegrated with water, and the resultant insoluble material (nickel and iron oxides) filtered off. The clear filtrate was acidulated with concentrated hydrochloric acid, and then made strongly alkaline with ammonium hydrate. The precipitate (silica and alumina from the caustic potash), which formed on the addition of the latter reagent, was filtered off, and magnesia solution added. The precipitate of magnesium ammonium arseniate, which formed after standing twelve hours, was filtered off, dissolved in dilute hydrochloric acid, re-precipitated with ammonium hydrate, filtered, dried, weighed and ignited in a platinum crucible, in the manner prescribed for this determination. The results obtained were as follows: (1) ·2777 gram of ore gave ·2853 gram of magnesium pyroarseniate = 49·73 per cent. arsenic; (2) ·1137 gram of ore gave ·1173 gram of magnesium pyroarseniate = 49·94 per cent. arsenic; (3) ·2548 gram of the ore was dissolved in nitric acid, evaporated to dryness, the residue taken up in hydrochloric acid, and the arsenic acid reduced with sulphurous acid. Hydrogen

sulphide was then added, the resulting arsenious sulphide filtered off, dissolved in nitric acid, the solution made alkaline with ammonium hydrate, magnesia mixture added, and the arsenic determined as above; ·2617 gram of magnesium pyroarseniate was found = 49·72 per cent. arsenic.

The insoluble residue remaining after the fusion was dissolved in water, was treated with nitric acid and evaporated to dryness. Hydrochloric acid was then added, and hydrogen sulphide passed through the solution for several hours, without the formation of any precipitate of sulphide of arsenic, showing that the mineral must have been completely decomposed.

Niccolite (*Ni.As.*)—With this mineral, the attempt was made to see what effect currents of greater intensity would have on the decomposition. It was hoped that with a current of greater strength the decomposition could be effected in less time, but as will be seen, the results, as far as a diminution of the time limit is concerned, are practically negative.

Two samples of the finely ground niccolite were subjected to a current which varied from 1½ to 1¾ ampères, for twenty minutes, and without any reversal of the current, 25–30 grams of caustic potash being used. In both cases did the residues which remained after disintegrating the fused mass with water, show the presence of arsenic, on treating the residues with nitric acid, evaporating to dryness, and the subsequent addition of hydrochloric acid and hydrogen sulphide. The presence of arsenic in the residues is probably due to the fact that the greater strength of current used in the decomposition, deposits larger quantities of metallic nickel on the cathode, enclosing at the same time appreciable quantities of undecomposed mineral.

A much weaker current was now tried. Two samples of the mineral were subjected to a current of half an ampère for twenty minutes, 25–30 grams of caustic potash being used. The result was the same as in the previous case, arsenic being found in both of the residues.

The time limit was now extended with more satisfactory results, the manner of decomposition being as follows: A

current of one ampère was allowed to pass through the fused mass for twenty-five minutes, the current passing up through the crucible. At the end of this time, the current was reversed for five minutes, to remove the metal and any undecomposed mineral that may have attached itself to the platinum wire. The subsequent operations of extracting the alkaline arseniate and weighing it as magnesium pyroarseniate, were similar to those already given under Gersdorfite, with the exception that instead of filtering the precipitation of magnesium ammonium arseniate through filter paper, and igniting it in a platinum crucible, the precipitate was filtered directly through a porcelain Gooch crucible, of the pattern recommended by Prof. Caldwell. Owing to the fine, granular condition of the precipitate, this requires some care, particularly if the filter pump be used. The best results were obtained by first placing a layer of glass wool in the crucible and covering this with a layer of asbestos. After filtering, the crucible with its contents was first dried on a hot plate until all moisture was removed, and then gradually heated over a Bunsen burner for an hour. In this time all the precipitate will be converted into magnesium pyroarseniate. It is hardly necessary to state that the flame from the burner should not be allowed to enter the crucible below, lest a partial reduction of the precipitate ensue. It was also found advisable to allow the crucibles to stand for twelve hours after ignition, since the constant change in temperature made appreciable differences in the weighings. The results were as follows; ·1209 gram of niccolite gave ·1301 gram of magnesium pyroarseniate = 52·09 per cent. arsenic; 0·1540 gram of niccolite gave 0·1672 gram of magnesium pyroarseniate = 52·55 per cent. arsenic.

The residues left after disintegrating the fusions gave no reactions for arsenic. They both had a peculiar crystalline appearance resembling minute plates. They dissolved in nitric acid without any evolution of nitrous fumes, and are probably oxide of nickel.

Another sample of the ore was dissolved in nitric acid, the excess of acid evaporated, ammonium hydrate added along with magnesia solution, and the arsenic determined

in the usual manner as magnesium pyroarseniate, the weighing being made in a platinum crucible, with the following result: 0·2611 gram of niccolite gave 0·2833 gram of magnesium pyroarseniate = 52·52 per cent. arsenic.

Arsenopyrite (*Fe.As.S.*)—The conditions under which arsenopyrite is decomposed are very similar to those of niccolite. The quantity of caustic potash used, the time of decomposition, the reversal of the current, etc., are precisely the same, the only difference between them lying in the fact that in the decomposition of arsenopyrite it was found that the current might vary from one to one and one-half ampères without affecting the decomposition. The method of determining the arsenic, as far as the Gooch crucible, etc., is concerned, was the same as under niccolite. Results as follows:

0·2168 gram of arsenopyrite gave 0·1729 gram of magnesium pyroarseniate = 38·6 per cent. arsenic.

0·1709 gram of arsenopyrite gave 0·1356 gram of magnesium pyroarseniate = 38·41 per cent. arsenic.

The residues from the fusions, treated similarly to those under niccolite, showed no traces of arsenic.

0·2306 gram of the ore were dissolved in concentrated nitric acid, evaporated to dryness, treated with hydrochloric acid and water, and any insoluble matter remaining, filtered off. The solution was then reduced with sulphurous acid, the excess removed by boiling, and the arsenic precipitated by hydrogen sulphide. The solution was then allowed to stand until the odor of hydrogen sulphide was barely perceptible, and then filtered on a porcelain Gooch crucible, washed with cold water, carbon disulphide and alcohol, dried at 100° C. and weighed. The result was 47·73 per cent. As. As the high result could be due to but one cause, viz: the presence of sulphur in the precipitate, repeated treatments with carbon disulphide and alcohol were given the latter, but without avail. The precipitate was eventually dissolved in nitric acid, and the arsenic thrown out with magnesia solution. Found: 0·1856 gram of magnesium pyroarseniate = 38·96 per cent. arsenic.

It will be seen from this, that the determination of arsenic

directly as arsenious sulphide by weighing on a porcelain Gooch crucible is not practicable. The method was tried with various other minerals, and in but one case was the result within limits, due more to accident than to any virtues of the method. The difficulty seems to lie in the fact, that the precipitate settles very compactly in the crucible, and prevents the carbon disulphide from obtaining more than a surface contact with it. In some instances, the crucible was placed in a beaker, covered with carbon disulphide, and allowed to stand for twenty-four hours, without any appreciable difference becoming manifest in the result.

Metallic Arsenic (*As.*)—In the oxidation of the metallic arsenic, a difficulty was encountered which the previous minerals had been free from. It was noticed that if the conditions previously mentioned were followed, viz: that the caustic potash be brought to a state of fusion, and the powdered mineral added, a volatilization of some of the arsenic invariably occurred. In fact, so rapidly did this take place, that barely did the mineral come in contact with the fused potash, but what the garlicky odor of arsenic was perceptible. To obviate this loss, the following method was found to be the best, and, in fact, the only one that would give accurate results. The caustic potash was introduced into the crucible, carefully heated to drive out all moisture, and eventually brought to complete fusion. The flame was now removed, and the mass allowed to cool until it was almost solid, when the powdered arsenic was carefully spread over the surface of the potash. The platinum wire is now placed in position and the current closed. Should the potash have cooled to such an extent that the current will no longer pass through the mass, or at least only with difficulty, a very small flame carefully played under the crucible will remedy the trouble. The arsenic, if these directions are complied with, becomes gradually oxidized, and no volatilization is perceptible. After the first ten minutes, the crucible may be gently heated, until its contents are again in a condition of fusion, and should be kept in such a state until the end of the oxidation. The current used for the operation registered one ampère in the Kohl-

rausch ampèremeter when the potash was completely fused. At the beginning of the oxidation, the resistance offered by the almost solid caustic potash is so great that the current barely registers, but this is exactly the condition that is desirable for thorough results. The current was allowed to run for thirty minutes, being reversed for the last five minutes. The results are as follows:

0·0974 gram of arsenic gave 0·1813 gram of magnesium pyroarseniate = 90·11 per cent. arsenic.

0·1052 gram of arsenic gave 0·1961 gram of magnesium pyroarseniate = 90·23 per cent. arsenic.

The very slight residues which remained after the fusions were treated with water, showed no signs of arsenic. The filtrates from the precipitations with magnesia solution were acidulated with hydrochloric acid and hydrogen sulphide added, to see if possibly some of the arsenic might be present as arsenious acid. No trace of the latter, however, was found.

Another sample of the powdered metal was dissolved in nitric acid, and the arsenic determined in the manner already indicated for the previously mentioned minerals, as magnesium pyroarseniate. It yielded 90·14 per cent. arsenic.

In the two determinations of arsenic in the metallic arsenic, given above, the magnesium pyroarseniate was weighed on porcelain Gooch crucibles.

Rammelsbergite $(Ni.Co.Fe.)As^2$.—With this mineral more difficulty was encountered than with any other, and the results that are given below were obtained only after *seventeen* attempts at decomposition proved unsuccessful. The method used at first was the one which showed itself to be efficient for the decomposition of metallic arsenic, viz: 25–30 grams of caustic potash and a current of one ampère running for thirty minutes, with five minutes reversal at the end of the oxidation. This proved an utter failure, as the residues from the fusion showed in all cases the presence of arsenic, while the results obtained varied from 53–67 per cent. of arsenic. A former experience having shown that the non-oxidation might probably be due to the enclo-

sure of particles of mineral on the platinum wire, a more frequent reversal of the current was tried. Using the same amount of caustic potash, and increasing the current strength from one to one and one-half ampères, the current was reversed after the first ten minutes, and allowed to run in the opposite direction for three minutes. It was then passed up through the crucible again for five minutes, then again down through the platinum wire for three minutes, the process being continued for thirty minutes. The results were altogether unsatisfactory, large quantities of arsenic being found in the residues.

The amount of caustic potash was now increased from 25–30 grams to 40 grams, the nickel crucible used being $1\frac{7}{8}$ inches high and 2 inches wide. In six decompositions made under these conditions, the current in the first two had a strength of one ampère, in the second two, of an ampère and one-half, and in the last two it was increased to one and three-quarters ampères, the current being reversed in a manner similar to the one previously tried. The results in all cases were of a negative order, as arsenic was found in all the residues. An increase of the time limit was now tried with satisfactory results. Using forty grams of caustic potash, the current was allowed to act for forty-five minutes. After various attempts to ascertain the best current strength for the purpose, it was found that a current that registers an ampère was the most satisfactory, and it should not be allowed to rise above this point, otherwise the decompositions are apt to be incomplete. In the oxidations given below, the current was reversed at the end of every ten minutes, for three minutes. Another phase of the operation that seems to be essential, is to have the mineral in as fine a condition as possible. Using the conditions just given, the residues from the fusions showed no arsenic, though they were most carefully examined by the wet method and also before the blow-pipe. The arsenic was precipitated as magnesium ammonium arseniate, and weighed as magnesium pyroarseniate in a platinum crucible, the filter being ignited separately after moistening with ammonium nitrate.

The results found were as follows: 0·1829 gram of rammelsbergite gave 0·2598 gram of magnesium pyroarseniate = 68·76 per cent. arsenic; 0·2168 gram of rammelsbergite gave 0·3118 gram of magnesium pyroarseniate = 69·62 per cent. arsenic.

Another sample of the mineral dissolved in nitric acid and determined as magnesium pyroarseniate gave 70·34 per cent. arsenic.

Chloanthite (*Ni.Co.Fe.*) As^2.—The mineral used for decomposition was a portion of the sample from Franklin, N. J., which was reported along with other minerals, by Dr. Koenig, in the *Proceedings of the Academy of Natural Sciences of Philadelphia*, 1889, 184. The decompositions were made contemporaneously with those of rammelsbergite, and for this reason many of the unsuccessful steps which were made with the latter mineral were also made with the chloanthite. The first oxidations were made with a current of one ampère, using 25–30 grams of caustic potash, and allowing the current to run for thirty minutes. As with the rammelsbergite, so here, too, only diverse results were obtained. Reversing the current every five minutes, after the first ten minutes, brought about a similar condition of affairs. The results were from five to six per cent. low. The addition of copper oxide, as recommended by Dr. Smith in the oxidation of pyrite (*Journal of the Franklin Institute*, proceedings of the Chemical Section, vol. 2, p. 62) was now tried. The quantity of caustic potash used being increased at the same time, with one sample of the chloanthite, an equal amount of copper oxide was mixed, and with another sample double the quantity of copper oxide. The other conditions were a current of one and one-half ampères, a time limit of thirty minutes, with reversals of the current after the first fifteen minutes, and forty grams of caustic potash. This combination of conditions gave no better results than the previous one. Satisfactory results were eventually obtained under the following conditions, the copper oxide being dispensed with entirely: The current was not allowed to register above one ampère, and the best results will be obtained if it is kept slightly below this

mark. Thirty minutes was found to answer for complete decomposition, but for the sake of certainty, it is advisable to allow the current to run for forty-five minutes, reversing it during the last five minutes. The amount of caustic potash used was forty grams. The results obtained were as follows: 0·2332 gram of chloanthite was decomposed as above. The fusion was treated with hot water and filtered. The filtrate was acidulated with hydrochloric acid, and warmed to expel the carbon dioxide present. On cooling, the arsenic was reduced with sulphurous acid, and after the expulsion of the excess of sulphurous acid, was precipitated with hydrogen sulphide in the cold. The precipitate of arsenious sulphide was filtered in a Gooch crucible, after the solution had stood until it barely had the odor of hydrogen sulphide, and washed with cold water. The crucible and its contents were then placed in a beaker, carbon disulphide added and allowed to stand twenty-four hours. The crucible was then removed from the beaker, its contents washed with alcohol, then with cold water, and finally dried for six hours at 105° C.; 0·2710 gram of arsenious sulphide was found = 70·84 per cent. arsenic; 0·2899 gram of chloanthite treated in the same manner as the preceding gave 0·3325 gram of arsenious sulphide = 69·93 per cent. arsenic.

In the sample of the mineral analyzed by Dr. Koenig and reported by him, he found 70·66 per cent. arsenic.

As will be seen from the above, accurate results were obtained by weighing the arsenic as arsenious sulphide. They are, however, but two out of a large number of determinations that were made in porcelain Gooch crucibles, and the only two which gave results sufficiently close to be utilized. The amount of sulphur precipitated with the arsenious sulphide must have been very small, otherwise the results, owing to the inefficacy of the carbon disulphide, would assuredly have been high. For this reason, the author cannot recommend the method for general use.

The residues from the fusions were carefully examined for arsenic but none was found to be present.

Smaltite (*Co.Ni.Fe.*) As^2.—From the experience gained

with rammelsbergite and chloanthite, it was found very easy to oxidize the smaltite. The mineral used for the purpose was mixed with gangue, and therefore was first broken up, and the smaltite picked out as carefully as possible by hand. The resultant material, as shown by the analyses, still contained impurities. The conditions for oxidation are as follows: A current of one ampère with the restrictions imposed under chloanthite, a time limit of forty-five minutes, and forty grams of caustic potash. Using those conditions, the oxidation is complete, the residues showing not the least trace of arsenic. The results obtained were as follows:

0·2233 gram of smaltite gave 0·2813 gram of magnesium pyroarseniate = 60·98 per cent. arsenic.

0·1790 gram of smaltite yielded 0·2199 gram of magnesium pyroarseniate = 59·47 per cent. arsenic.

The method of procedure resembled one already given. The fusion was acidified with hydrochloric acid, then made alkaline with ammonium hydrate, and the arsenic precipitated with magnesia solution, being finally weighed in a platinum crucible. In the latter of the two determinations, the garlic odor of arsenic was noticeable on igniting the filter paper, although it had previously been thoroughly saturated with a concentrated ammonium nitrate solution. This accounts for the slightly low result obtained, but it was not thought necessary to repeat the operation, since the residue showed that the oxidation was complete.

0·3136 gram of the ore, dissolved in nitric acid, and the arsenic determined as magnesium pyroarseniate in a platinum crucible, gave 0·3929 gram of magnesium pyroarseniate = 60·65 per cent. arsenic. The difference in percentage from the theoretical amount is due to the impurities in the mineral.

A study of the composition of rammelsbergite, chloanthite and smaltite will show several points of interest. It will be seen from their formulæ that they each contain two atoms of arsenic to the molecule, while niccolite, cobaltite, arsenopyrite, etc., either have one atom of arsenic to the molecule or have one atom of arsenic replaced by sulphur.

Returning to the study of the conditions necessary for oxidation, it will be remembered that the amounts of caustic potash necessary, and the extents of time, were larger for the first three minerals than for any of the others, while the oxidations seem to proceed with greater difficulty. A cause for this that might be advanced, is that the oxides of the metals are united with greater tenacity to two arsenic atoms than they are to one, and require a greater expenditure of force for their separation. A somewhat similar occurrence was noticed by Dr. Smith in the oxidation of the metallic sulphides. Pyrrhotite, whose formula is in all probability either $Fe_{11}S_{12}$ or FeS, is decomposed with great readiness, while pyrite, which contains two atoms of sulphur to the molecule, succumbed only after repeated and many fruitless trials. What might be considered a curious feature in the oxidation of these arsenides is the fact that those containing two atoms of arsenic to the molecule are decomposed more readily by weak currents than they are by strong ones, while with the arsenides containing but one atom to the molecule, either strong or weak currents are equally efficacious. The only explanation that there is to offer for this seeming anomaly, is the one already given, viz: the enclosure of particles of metal on the platinum wire. In those arsenides containing but one atom of arsenic to the molecule, the decomposition is in all probability so rapid, that any enclosure of the mineral on the wire is practically impossible. In minerals like rammelsbergite and chloanthite we may assume that the decomposition proceeds by much slower stages, so that if the current is sufficiently strong to deposit metal on the cathode, there is constantly present sufficient undecomposed mineral to be enclosed in the deposited metal.

Cobaltite (*Co.Fe.*)*As.S.*—This mineral was decomposed with great ease, a result to be expected if we trace the similarity in composition between it and such minerals as gersdorfite, niccolite, etc. The conditions for oxidation are very similar to those of gersdorfite, with the difference, that while, in the latter, the current was allowed to run only for twenty minutes, in the decomposition of cobaltite it ran for

thirty minutes, with a five minutes reversal at the end. Otherwise the conditions for oxidation and for the subsequent decomposition of the fusion and the estimation of the arsenic, are the same as for gersdorfite. The magnesium pyroarseniate was weighed in platinum Gooch crucibles, the method being very accurate, owing to the fact that there is no possibility for any volatilization of the arsenic, and more rapid than weighing in a porcelain Gooch crucible, since the platinum crucible attains a constant temperature in a very short period of time. The results obtained were as follows:

0·1032 gram of cobaltite yielded 0·1006 gram of magnesium pyroarseniate = 47·2 per cent. arsenic.

0·1326 gram of cobaltite yielded 0·1313 gram of magnesium pyroarseniate = 47·93 per cent. arsenic.

0·2250 gram of the same ore was dissolved in nitric acid, the acid evaporated, the solution made alkaline with ammonium hydrate, and the arsenic precipitated with magnesia solution. The resultant magnesium ammonium arseniate was ignited in a porcelain Gooch crucible and gave 0·2229 gram of magnesium pyroarseniate = 47·96 per cent. arsenic.

Orpiment (As_2S_3).—The preliminary investigations made with this mineral showed that it came under the same category as the metallic arsenic. When the finely powdered mineral was introduced into the molten caustic potash, a volatilization of the arsenic, recognizable by its odor, occurred. The precautions given under metallic arsenic, regarding the cooling of the caustic potash and the regulation of the current, were then introduced, with successful results. Some difficulty may at first be experienced in obtaining correct control of the operation, but a few oxidations will give the operator sufficient experience to bring the decomposition to a successful completion. The conditions best adapted for the work are a current of one ampère, 25–30 grams of caustic potash, the current being allowed to run for thirty minutes. Using these conditions, no arsenic was found in the slight residues which remained after decomposing the fusion, nor was any odor of arsenic perceptible during the entire course of the operation.

0·1443 gram of orpiment, decomposed according to the directions, gave 0·1761 gram of magnesium pyroarseniate = 59·08 per cent. arsenic.

0·1044 gram of orpiment yielded 0·12805 gram magnesium pyroarseniate = 59·38 per cent. arsenic.

0·2233 gram of the same ore, dissolved in nitric acid, and weighed as magnesium pyroarseniate in a platinum crucible, yielded 0·2755 gram of magnesium pyroarseniate = 59·72 per cent. arsenic.

Proustite (Ag_3AsS_3).—But a very small quantity of the mineral was available for analysis, and even that was intimately mixed with argentite. No attempt was therefore made to extract the former mineral by hand-picking, but the entire mixture was placed in an agate mortar and ground, the grindings then being passed through a sieve. This removed all the proustite with some of the argentite, the greater portion of the latter remaining behind as flattened plates. Sufficient argentite, however, remained with the proustite, to reduce in a considerable measure the percentage of the arsenic, and the deviation of the results from the theoretical percentage is attributable to this cause. Sufficient material was not at hand to make a check analysis, by dissolving the mineral in nitric acid and determining in the usual way, but as the residues were most carefully examined for arsenic, and as none was found to be present, the natural conclusion arrived at was, that the decomposition was complete. No loss of arsenic was noticeable during the entire operation, and the closeness of the results indicates that the decomposition of this mineral by the electric current can be accomplished as successfully as any one of those previously described. The conditions for oxidation were as follows: A current of one ampère running for thirty minutes, the current being reversed during the last five minutes. The amount of caustic potash used was 25–30 grams. Below will be found the results obtained:

1·1589 gram of proustite, weighed as magnesium pyroarseniate in a porcelain Gooch crucible, gave 0·0147 gram of magnesium pyroarseniate = 4·48 per cent. arsenic.

0·2255 gram of proustite yielded 0·0249 gram of magnesium pyroarseniate = 5·34 per cent. arsenic.

Besides these minerals already recorded, several others were subjected to oxidation by the current, but owing to lack of material for the continuance of the work, satisfactory conclusions were not reached. The results are, however, of interest, and are, therefore, here appended.

Domeykite in Niccolite, $n(Ni.As.) + m(Cu^3As.)$—The mineral used for oxidation came from Michipicoten Island, and was a small section of a specimen in the mineral collection of the University of Pennsylvania, labelled whitneyite. Two oxidations of the mineral, in which the residues still showed arsenic, gave, to the surprise of the author, 35·3 per cent. and 40·04 per cent. of arsenic, respectively, showing that the mineral could not be whitneyite, since this should contain theoretically 11·64 per cent. of arsenic. A later oxidation gave, using 0·2207 gram of the mineral, 0·2016 gram of magnesium pyroarseniate = 44·22 per cent. arsenic. 25–30 grams of caustic potash were employed, with a current of one to one and one-half ampères, for thirty minutes, reversing the current at the end for five minutes. In this oxidation no trace of arsenic was found in the residue. On reporting the results obtained to Dr. Koenig, he made an analysis of another sample, by dissolving the mineral in nitric acid, and found it to contain 47 per cent. of arsenic. This result is, however, not inharmonious with the last one obtained by the current, since, in a fresh fracture of the mineral, the niccolite and domeykite can be seen lying alongside of each other. Owing to this non-homogeneity, the sample analyzed by Dr. Koenig may have contained more niccolite than the one used for oxidation by the current, and gave proportionately a higher percentage of arsenic. Unfortunately, the scarcity of the mineral necessitated the discontinuance of the work, and the question of complete oxidation is still in doubt. The few per cent. difference in the results obtained by the two methods, however, indicates that the decomposition can be successfully accomplished under the conditions mentioned above.

Enargite ($3Cu^2S.As^2S^5$).—The material used for decompo-

sition contained an admixture of gangue, and as with the domeykite, not sufficient of the substance was obtainable to settle thoroughly the question of oxidation. As the percentage of arsenic found, however, is within the neighborhood of what the mineral ought to contain, and as no arsenic was detectable in the residue from the fusion, the result obtained is here appended, without any definite statement regarding the thoroughness of the method. The amount of caustic potash used in the oxidation was 25–30 grams, the current strength one ampère, with a reversal of the current at the end of the operation for five minutes. The arsenic was determined by weighing as magnesium pyroarséniate on a porcelain Gooch crucible.

0·2840 gram of enargite gave 0·0770 gram of magnesium pyroarseniate = 13·12 per cent. arsenic.

The theoretical percentage of arsenic in the mineral is 19·1 per cent. If we remember, however, that the sample used contained gangue material, and that no arsenic was found in the residue, it is but fair to assume that the result lies within the limits of error, and that the oxidation is complete. No positive statement, however, can be made.

A study of the methods used for the determination of the arsenic in the various oxidations, will be of interest. As has already been stated, the determination of the arsenic as arsenious sulphide, by weighing on a porcelain Gooch crucible, cannot be recommended, owing to the great difficulty experienced in removing the sulphur with which the precipitate of arsenious sulphide is contaminated. The more common method of weighing the arsenic as magnesium pyroarseniate was found to be accurate, if the conditions laid down for this determination are complied with, the method requiring at the same time great care. In the incineration of the filter from the magnesium ammonium arseniate, constant vigilance was required to prevent a volatilization of a portion of the arsenic, even though the filter had been previously saturated with a concentrated ammonium nitrate solution. And in many cases it was necessary to moisten the burnt filter several times with the solution

before it could be completely reduced to ash. Weighing the precipitate on either a platinum or porcelain Gooch crucible removes these sources of error, and is, of all the methods so far mentioned, the most to be recommended. In the precipitations with magnesia solutions, it was noticed that the presence of large quantities of alkaline salts have a tendency to materially retard the precipitation of the magnesium ammonium arseniate, and it became necessary to allow the solution to stand at least forty-eight hours before the precipitation was complete. For this reason, where large quantities of alkaline salts are known to be present, for example, the caustic potash used in the fusion, it may be more advisable to reduce the arsenic with sulphurous acid, precipitate it as arsenious sulphide, filter and wash, and then reconvert it into arsenic acid and determine as magnesium pyroarseniate.

Owing to the time and care required in the above determinations, the method described in *Sutton's Volumetric Analysis*, sixth edition, as recommended by Pearce, of the Colorado Smelting Company, was tried. The substance of the method is as follows: "The arsenic brought into the form of alkaline arseniate is acidified with nitric acid, and boiled to remove carbon dioxide and nitrous fumes. It is then cooled to the ordinary temperature, and almost exactly neutralized as follows: Place a small piece of litmus paper in the liquid; it should show an acid reaction; now gradually add strong ammonia until the litmus turns blue, avoiding a great excess. Again make slightly acid with a drop or two of strong nitric acid, and by means of very dilute ammonia and nitric acid, added drop by drop, bring the solution to such a condition that the litmus paper, after having previously been reddened, will, in the course of half a minute, begin to show signs of alkalinity. The litmus paper may now be removed and washed, and the solution, if tolerably clear, is ready for the addition of silver nitrate. If the neutralization has caused much of a precipitate (alumina, etc.), it is best to filter it off at once, to render the subsequent filtration and washing of the arseniate of silver easier, ——." The latter portion of the process consists in

determining the silver in the silver arseniate, and calculating the percentage of arsenic from the amount of silver found.

A number of determinations were made by the author to ascertain the value of the method, but all of the attempts made resulted in failure. It was found well nigh impossible to tell by the color of the litmus paper whether the solution was acid or alkaline. In several cases, methyl orange was used as an indicator, and while the solution was made slightly alkaline, as recommended by Pearce, the addition of ammonia to the filtrates invariably brought down considerable quantities of silver arseniate, and the results obtained were proverbially low. The silver was not determined by titration, as recommended by Pearce, but by electrolysis. The best result obtained by this method, with the details of the operation, are given below:

A sample of rammelsbergite was decomposed under the conditions mentioned for that mineral. The fusion was decomposed with hot water, the insoluble material filtered off, and the clear filtrate acidified with nitric acid and boiled to remove the carbon dioxide. On cooling, ammonium hydroxide was added, the precipitated alumina, etc., filtered off, and the additions of dilute nitric acid and dilute ammonia made according to Pearce's direction, until the solution became faintly yellow, methyl orange having been used as an indicator. Silver nitrate was now added, the solution stirred, and the precipitate of silver arseniate filtered off. The addition of a drop of ammonium hydrate to the clear filtrate gave a further precipitation, and ammonia was, therefore, added until the precipitation was supposed to be complete. The two precipitates were then united, washed with cold water, dissolved in nitric acid and the excess of acid evaporated. To the solution, ammonium hydrate was added until the solution became alkaline, and then an excess of potassium cyanide, the solution electrolyzed and the resultant silver weighed. 64·21 per cent. of arsenic was found, the same sample giving, by the pyroarseniate method, 70·34 per cent. arsenic.

The author believes that with continued practice, sufficient dexterity might be obtained with the method to obtain

accurate results, but it is hardly one that could be recommended for work outside of a technical laboratory, where absolute accuracy is not so essential a feature, as that the results should be correct, relatively, to each other.

A comparison of the oxidation of the metallic sulphides with that of the metallic arsenides shows several points of difference. In the oxidation of the sulphides, it was observed by Dr. Smith that the process took place in three stages, the sulphur being first oxidized to hydrogen sulphide, then to sulphurous acid and eventually to sulphuric acid. A similar state of affairs was not observed with the arsenides, and the oxidation evidently proceeds directly from metallic arsenide to arsenic acid. Even in samples where the oxidation had not been complete, and where the residues still showed undecomposed material, the filtrates from the fusion showed no trace of arsenious acid after the alkaline arseniate had been removed by precipitation with magnesia solution.

In conclusion, the author would here express his sense of deep obligation to Dr. Edgar F. Smith, for his unremitting kindness during the progress of the above work, and for his constant help in assisting its completion.

Thanks are also due to Dr. George A. Koenig for samples of minerals, and to Mr. D. L. Wallace, of this laboratory, for assistance rendered in the oxidations.

UNIVERSITY OF PENNSYLVANIA,
PHILADELPHIA, August 3, 1891.

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting of the Electrical Section, held Tuesday, November 3, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 3, 1891.

Prof. EDWIN J. HOUSTON, President, in the chair.

Present, thirty-five members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer's bill for printing and clerical work was approved and ordered paid.

Four nominations to membership were referred to the Committee on Admissions, who reported one election since last meeting.

Prof. Edwin J. Houston read a paper, entitled "Is Actinism a Species of Electrolysis?" Referred for publication.

Mr. Willyoung presented a communication on "Resistance Standards: their Manufacture and Adjustment." Referred for publication.

Mr. W. H. Edgerton described "Some Proposed Improvements in the Secondary Battery."

Mr. W. W. Jennings, under the title of "Jove's Autograph," exhibited and described a large and very interesting collection of lantern slides from lightning photographs, most of which were taken by himself; these showed the electrical discharge in many curious shapes, but with an entire absence in all of them of the zigzag form commonly seen in pictorial representations.

The following nominations were made for officers for the year 1892:

President—Prof. Edwin J. Houston.

Vice-President—Messrs. C. W. Pike and Carl Hering.

Secretary—Prof. L. F. Rondinella.

Treasurer and Conservator—Dr. Wm. H. Wahl.

The meeting then adjourned.

L. F. RONDINELLA, *Secretary*

Is ACTINISM a SPECIES of ELECTROLYSIS?

By Prof. Edwin J. Houston.

[*Read at the stated meeting, held November 3, 1891.*]

In the present paper I have arranged and amplified the substance of the informal remarks made at the last meeting of the section, concerning the possible identity of actinism in the growing leaf, when exposed to the sunlight, and electrolytic decomposition.

In the growing leaf, in sunshine, a series of complex decompositions occur, which result finally in the deposition of carbon and the evolution of free oxygen.

Assimilation in plants consists, with few exceptions, in a process of deoxidation. The food materials absorbed by plants are generally highly oxidized substances, which are deoxidized during assimilation. This assimilation takes place mainly in cells containing chlorophyll, and this, almost without exception, occurs only in the presence of sunlight.

Sachs, in his *Text-Book of Botany*, says: "It is only the cells that contain chlorophyll, and these only under the influence of sunlight, that have the power of decomposing the carbon dioxide taken up by them, and, at the same time, setting free an equal volume of oxygen, in order to produce organic compounds out of the elements of carbon dioxide and water; or, in other words, to assimilate."

In nearly every species of plants the leaf is presented with one of its faces towards the sunlight, so that one face is illumined and the other non-illumined; or, at least the illumination of one face exceeds the illumination of the opposite face. This latter is especially the case with leaves that are formed of comparatively transparent substances.

That differences of potential exist in the various parts of a growing plant is a fact that is now generally recognized. Too little, however, has been done in this direction to ascertain the exact character of these differences of potential.

Probably one reason so little is correctly known to-day concerning the differences of potential of growing plants, arises from the fact that such differences of potential can be brought about by so many different causes, that probably the differences of potential arising from one cause or set of causes, mask or neutralize those produced by another cause or set of causes.

I desire in the present paper briefly to call attention to another probable source of difference of electric potential, that may still further mask or render difficult of detection the differences of potential existing naturally in growing plants.

Before doing this, however, I will briefly review some of the more important causes which produce differences of potential in growing plants. The principal of these are as follows, namely:

(1) Various chemical processes that occur in the cell walls of the growing plant.

(2) Molecular movements of liquids throughout the plant, which result in the production of diaphragm currents. These molecular movements may either be those caused during the growth of the plant, or may be caused by the mere bending of the plant, by the wind, or other cause external to the plant.

(3) Differences of potential developed in plants which would result in currents of the general character of the demarcation currents observed in animals; that is, currents due to the chemical action of the various liquid materials exuded at the surfaces of injured or abnormal plant tissue.

(4) Differences of potential due to the evaporation of moisture from the surfaces of the leaves, derived either from the rain or dew, or from the evaporation of liquid substances given off from the body of the plant.

(5) Differences of potential arising from the electrolytic decomposition of carbonic acid, or the various forms which carbonic acid derivatives assume during assimilation.

The causes above enumerated, refer to the differences of potential that have their seat in the structure of the plant

itself. Another source of differences of potential is to be found in the differences of electric potential that generally exist between the atmosphere that surrounds the plant, and the earth or soil in which it grows. These differences of potential being neutralized in the various parts of the plant itself would, of course, result in the production of electrical currents.

I desire to call special attention to the fifth head under which I have classed differences of electric potential in plants, viz: those arising from the electrolytic decomposition of the various oxygenated carbon compounds, derived mainly, if not entirely, from the carbonic acid of the atmosphere.

That the action of sunlight on growing plants should partake of the nature of electrolytic decomposition is, perhaps, to be inferred from the general views now held in accordance with Hertz's theory as to the identity between sunlight and electro-magnetic radiations or waves.

These remarks should be regarded merely as suggestions made in the line of further investigations.

As far as our knowledge of growing plants extends the oxygen which results during the general process of deoxidation, under the influence of sunlight appears to be evolved mainly from the non-illumined or darker face of the leaf, while the carbon, or the less highly oxidized carbon compounds, which are utilized by the plant for the production of its woody fibre and woody tissue, though afterwards deposited in all parts of the leaf, are probably mainly liberated at or near the illumined face.

If these facts be as above-mentioned, the decomposition in the leaf under the action of sunlight, of the carbonic acid, or its derivative compounds probably partakes of the nature of electrolytic decomposition.

In this direction I would suggest the following lines of investigation, namely:

(1) To ascertain experimentally whether there exists on the opposite faces of a growing leaf, when exposed to the full action of sunshine, a difference of electric potential resulting from the polarization which always accompanies

electrolytic decomposition; and if this be so, what is the nature of such polarization.

If such differences of potential actually exist, it would of course follow, that the illumined face of such leaves, under polarization, would be mainly electro-negative, since it is at or near this face that the carbon and less highly oxidized carbon compounds appear, while the dark or less illumined face would be electro-positive, since it is here, for the greater part, that the oxygen is liberated.

(2) Whether electrodes suitably connected to the opposite faces of a growing leaf in the presence of sunshine, will show the presence of an electric current arising from an equalization of the difference of electric potential.

The value of these differences of potential on the opposite faces of growing leaves, might, of course, be ascertained by the proper use of an electrometer.

(3) Whether a suitable leaf-battery could not be devised, by connecting, in alternate succession, the opposite faces of a series of leaves on a plant-stalk.

That is to say, connect the illumined face of one leaf with the non-illumined face of another leaf, and so on in series until any feeble differences of electric potential that there might exist are sufficiently multiplied to sensibly affect the needle of a galvanometer.

(4) A comparison of the effects of sunlight and artificial light, such as the electric light, on such electrolytic decompositions.

(5) Whether any differences exist in the case of the light produced by an alternating-current arc light and that produced by a constant-current arc light.

(6) Supposing the presence of the differences of electric potential due to the electrolytic decomposition, to be established, and the direction of the electric currents so produced, known, to ascertain whether an electric current led through the plant in the same direction as the current produced by actinism, would not tend to increase the assimilation and the subsequent growth of the plant; and, whether, on the contrary, an electric current sent in the opposite direction through the growing leaf would not tend to check such assimilation or growth.

According to some experiments recently made in France, it was shown that electric currents sent through plants under certain circumstances promoted growth. These currents were sent through the soil in which the plants were growing, by electrodes placed in the soil. The nourishing substances in a quantity of manure, placed near one of the electrodes, were clearly carried in the line of the current, or between the electrodes.

(7) To ascertain experimentally whether the converse of the proposition is true: namely, whether an electric current of approximately the same strength as that produced by actinism, when sent through the leaf in the opposite direction, would not result in the production of luminous phenomena in the leaf.

The following facts, well recognized in botany, would seem to show, to some extent at least the presence of a species of polarization in certain plants during active growth in sunshine.

In the case of those plants which bend or become concave on the side the most exposed to light: This curvature is due to the fact that a smaller growth occurs on the illumined than on the dark side. This is well recognized in botany, and such plants are called in general *heliotropic* plants. Since they are for the most part highly transparent, considerable light must therefore pass through their entire structure, and the difference in the illumination between the light and dark faces must be comparatively slight. This shows that such differences in growth may occur under comparatively small differences of illumination.

In the case of plants that turn toward the sun: It is a well-known fact that some plants turn towards the light. It is possible that this motion is in some manner the result of the polarization effected, during growth, by the sunlight.

In a series of experiments concerning the effects of the electric light on plant growth, made at the Experimental Station of Agriculture of the Cornell University, some important facts were discovered concerning electric plant-culture.

These experiments seem to show that electric light pro-

motes plant assimilation, and sometimes hastens plant growth and therefore maturity.

The Cornell experiments made during 1889 and 1890 were with the light of a constant current Brush arc lamp. Those made during 1891 were with the light of a Westinghouse alternating current arc lamp.

It would seem to be a matter of considerable interest in the case of these experiments to ascertain definitely, whether any marked differences exist between the action of the light produced by a steady current and that produced by an alternating current. In the line of investigations here suggested, it would of course seem as if the electric decomposition would be less marked in the case of the light produced by an alternating current than that produced by a steady current. And that therefore in those cases where the electric light of the steady current had proved to be injurious to the growth and assimilation of the plants, that with the alternating current light such injurious effects should be less marked.

CORRESPONDENCE.

THE PATH OF A PROJECTILE.

To the Committee on Publications:

Capt. Ingalls, in the November impression of the JOURNAL, takes the occasion to say that the equations given in my October article are to be found in his treatise on *Ballistics*. I desire to state in reference to the subject that the equations given by me were deduced independently of Capt. Ingall's work, and without knowledge of its existence.

I merely stated that the equations were not *generally* given in treatises on mechanics, which statement virtually implied that they had been given before. Capt. Ingalls, however, was not the first to give these equations, although he seems to imply it. If Capt. Ingalls will refer to Newton's *Principia*, book second, proposition four, and translate its geometrical language into analytical symbols, he will obtain all the equations that he has given on the subject.

Very respectfully,

F. GILMAN.

Lowell, Mass., November 16, 1891.

BOOKS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

A Practical Guide to the Testing of Insulated Wires and Cables. By Herbert Laws Webb. New York: D. Van Nostrand Company. 1891. 12mo, pp. 8–118.

How to Make Inventions or Inventing as a Science and Art. Edward P. Thompson. New York: D. Van Nostrand Company. 1891. 8vo, pp. 161.

The Practical Catechism. A collection of questions on technical subjects, * * * By Robert Grimshaw. New York: John Wiley & Sons. 1891. 24mo, pp. 296. Price, $1.25.

Experiments and Researches on Trap Siphonage. Presented at the Eighteenth Annual Meeting of the American Public Health Association, 1890. By James E. Denton. Concord: Republican Press Association. 1891. 8vo. Pamphlet.

Modern Practice of the Electric Telegraph. By Franklin Leonard Pope. New York: D. Van Nostrand Company. 1891. 8vo.

The Eleventh Census. An Address delivered before the American Statistical Association. By Robert P. Porter. Boston, October 16, 1891. New York Engraving and Printing Company. 1891. 8vo. Pamphlet.

John Wiley & Sons announce the early publication of *The Engine Runners' Catechism*, telling how to erect, adjust and run the principal steam engines in use in the United States; being a sequel to the author's *Steam Engine Catechism*. (Profusely illustrated.) By Robert Grimshaw, M.E. (18mo. Cloth. Price, $2.00.) Also a ninth edition of *The Steam Engine Catechism*, by the same author. (18mo. Cloth. Two volumes in one. Price, $2.00.) Also, *Roofs and Bridges*. Part 3. By Prof. Mansfield Merriman.

BOOK NOTICES.

A Short Manual of Analytical Chemistry. Qualitative and Quantitative; Inorganic and Organic. By John Muter, M.A., Ph.D., F.R.S.E., F.I.C., F.C.S., etc. Edited by Claude Hamilton, M.D., Ph.G., Prof. of Anal. Chem. in the Min. Med. Col., and Kansas City Col. of Pharmacy, etc.

The treatise attempts to cover a very wide range of practical or laboratory instruction, including qualitative and quantitative mineral analysis, detection

of the alkaloids and more commonly occurring glucosides, ultimate organic analysis, special schemes for drug analysis, urinary analysis, analysis of water, air and important foods, together with gas analysis, and the methods of the polariscope and spectroscope.

It is obvious that some parts of this wide field can only be touched upon in the most superficial way.

The qualitative tests seem to be full and satisfactory, notably those for the acid radicals, the volumetric methods are also quite complete, the quantitative sections, however, are hardly more than an outline, while the sections on gas analysis and the polariscope might as well have been omitted for any practical value they will possess to the student.

The book is, however, a valuable compend of information for the student of analytical chemistry. S. P. S.

Hints to Power Users. By Robert Grimshaw. New York: Cassell Publishing Company, 1891. (pp. 160. $1.00.)

The sub-title perhaps more fully explains the intended use of the work, and better than any other language would: it is "Plain, practical pointers, free from high science, and intended for the man who pays the bills."

The advice given is directly to the point, and the book is a good one to be put in the hands of the engine or boiler man about an establishment, after the man who pays the bills has read it. The range covered is, as the author puts it, "from the ash-pit to the exhaust head," and he might have added "taking in all the rest of the mill." H. W. S.

The Patent Franchise in the United States. By G. H. Knight. Temple Court, New York City. (Author, April, 1891.)

It is rarely that any concise publication handles an important subject so well as this. In twenty-four handsomely printed pages, Mr. Knight has given a clear and exact statement of the history of the recognition of property in inventions by protective legal enactments, and the development of public sentiment toward such protection; moreover, he has done so in a very entertaining way and so far as the opponents to patent protection of invention are amenable to reason, he has disarmed them by an array of indisputable facts.

No one can attentively read Mr. Knight's little book without realizing that every inhabitant of this country has either directly or indirectly been benefited by the legal recognition of the patent franchise, although there are doubtless many who don't know it, and demagogues ready to work upon their ignorance have raised prejudices against the patent system. In one particular this work is eminently worthy of public attention, it is in the plea it makes for appropriation by Congress of sufficient money, out of the millions accumulated in the treasury from inventors' fees in excess of expenses, to enable the Patent Office to prepare and publish classified

abridgments of the patents already granted, and to adequately remunerate a competent examining corps.

If a portion of the attention, energy and time now expended in Congress in cultivating the opportunities of political placemen could be devoted to the material interests fostered by the patent laws, such action might be hoped for, but the inventors and patentees have no lobby. Mr. Knight is working ably in the right direction in a good cause, in which the Franklin Institute has distinctly and repeatedly defined its position; he deserves the hearty co-operation of every intelligent citizen, and should succeed. S. L. W.

Prof. R. Koch's Method to Cure Tuberculosis. Popularly treated by Dr. Max Birnbaum. Translated from the German. Milwaukee, Wis., H. E. Haferkorn, 1891.

The translator, in his preface, makes the cheering announcement that consumption can be cured, presumably by Koch's lymph. This announcement is as yet premature, for although "'tis a consummation devoutly to be wished," the statement is scarcely sustained by the results of the many practical tests that have been made.

The book is a very interesting and readable one, and without being at all verbose, is one of the most complete essays on tuberculosis and its ravages, and one that may warmly be recommended to the student of medicine, since the author states clearly and concisely the nature of the dread malady together with the parts most frequently attacked by it. While not agreeing with the author in all his ideas with regard to the inception of tuberculosis, the writer can, however, most cordially agree with him and recommend his ideas regarding the hygienic measures which he advises for the prevention of the development of, and as assistants to, the cure of the disease. Means which tend to build up the physical health where a predisposition to this disease exists, act upon the same principle as a reinforcement to an army which is being besieged by an enemy—whichever side is the stronger must hold the other in check; and in this almost universal and dread disease, it is easier to keep the disease from developing by avoiding any exciting cause than to cure when it once asserts its power; an ounce of prevention in this particular instance being worth many pounds of attempted cure. G.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, Nov. 18, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 18, 1891.

Mr. JOS. M. WILSON, President, in the chair.

Present, seventy-two members and twelve visitors.

Additions to membership since last report, seventeen.

The Secretary read a letter from Prof. George Forbes, of London, England, accepting election as an honorary member; also, one from Mr. J. C. Trautwine, Jr., accepting election to the Board of Managers, to fill the unexpired term of John J. Weaver, deceased.

Mr. B. E. Fernrow, Chief of the Division of Forestry, Department of Agriculture, read a paper on the Government Timber Tests at present being undertaken in the Forestry Division of the Department, describing the objects to be accomplished, the need of such investigation to furnish reliable data regarding the properties of our various timbers, and for the information of all who require to use wood in building, engineering and manufacturing, and describing the plan and methods proposed for carrying on the work. The paper was illustrated by the exhibition of charts and photographs of test pieces. The paper was referred for publication.

Mr. H. Reed exhibited and described a series of photographs, showing the progress of the work of construction upon the terminal and elevated railway of the Philadelphia and Reading Railroad in Philadelphia.

The Secretary presented a series of views of the buildings of the World's Columbian Exposition, to be held in Chicago in 1893. He exhibited also a view of the projected suspension bridge over the North or Hudson River at New York, the construction of which is contemplated by the North River Bridge Company. This bridge is intended to carry across the river and directly into the metropolis, the tracks of the ten or more railroads terminating in Jersey City, and would afford much needed relief in the transfer of freight across the North River. On account of the great increase of the traffic of the railroads at this location, the present methods of transfer by barges is found to be entirely inadequate. The design of this bridge contemplates a suspension structure crossing the river with a single span of about 3,000 feet and providing for fourteen railway tracks to accommodate the heaviest traffic.

Mr. W. N. Jennings continued the exhibition of his series of local pictures.

Adjourned.

WM. H. WAHL, *Secretary.*

PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW.

FOR MAY, 1891.

Prepared under the Direction of the Committee on Meteorology of the Franklin Institute.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 31, 1891.

TEMPERATURE.

The mean temperature of 52 stations for May, 1891, was 57°.5, which is about 2°.5 below the normal, and 1°.3 below the corresponding month of 1890.

The mean of the daily maxima and minima temperatures 69°.2 and 45°.4 give an average daily range of 23°.8, and a monthly mean of 57°.3.

Highest monthly mean, 61°.0 at Philadelphia, S. O.

Lowest monthly mean, 51°.0 at Wellsboro.

Highest temperature recorded during the month, 93°.0 on the 10th at Carlisle and McConnellsburg.

Lowest temperature 20°.0 on the 4th at Dyberry.

Greatest local monthly range, 64° at Hollidaysburg and Dyberry.

Least local monthly range, 48° at Erie, S. O.

Greatest daily range, 53° at Hollidaysburg on the 10th.

Least daily range, 2° at Wellboro on the 18th.

From January 1, 1891, to May 31, 1891, the excess in temperature at Philadelphia was 258°, at Erie 250°, and at Pittsburgh 222°.

The warmest days of the month were the 10th and 11th. The coldest were the 4th, 5th, 6th, 7th and 17th.

BAROMETER.

The mean pressure for the month, 30.07, is about .07 above the normal. At the U. S. Signal Service Stations, the highest observed was 30.42, at Philadelphia, on the 20th, and the lowest 29.76 at Philadelphia, on the 16th.

PRECIPITATION.

The average precipitation, 2.12 inches for the month, is a deficiency of about one and a quarter inches. The largest totals in inches (including melted snow) were Ligonier, 4.41, and Somerset, 4.16.

The least were Blue Knob, 0.31; Wysox, 0.49, and Lewisburg, 0.67.

The largest monthly snowfall totals in inches were Columbus, 2·00; Wellsboro, 1·50, and Meadville, 1·50.

WIND AND WEATHER.

The prevailing wind was from the Northwest.

Average number: Rainy days, 8; clear days, 10; fair days, 10; cloudy days, 11.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Hamburg, 22d; Blue Knob, 20th, 22d, 30th; Hollidaysburg, 20th, 22d; Le Roy, 30th; Quakertown, 22d; Johnstown, 20th, 21st, 30th; Emporium, 20th, 31st; State College, 20th; Coatesville, 11th, 22d; Kennett Square, 3d, 22d; Westtown, 11th, 20th; Carlisle, 22d, 26th; Swarthmore, 11th, 20th, 22d, 31st; Huntingdon, 20th, 21st, 22d, 30th; Lancaster, 3d, 11th, 22d; Lebanon, 22d; Pottstown, 3d; Philadelphia, 11th, 20th, 22d; Girardville, 15th, 20th, 24th; Selins Grove, 20th, 22d; Somerset, 21st, 22d, 30th; Wellsboro, 20th, 30th; Lewisburg, 21st; Columbus, 20th, 22d; Ligonier, 20th, 21st, 30th; Meadville, 21st, 30th; York, 11th, 22d.

Hail.—Coatesville, 11th; Phœnixville, 11th; Selins Grove, 22d; Wellsboro, 6th.

Snow.—Hamburg, 6th; Blue Knob, 4th; Hollidaysburg, 6th; Le Roy, 5th, 6th; Johnstown, 6th; Emporium, 5th; Mauch Chunk, 6th; Rimersburg, 5th; Lock Haven, 5th; Carlisle, 6th; Harrisburg, 6th; Swarthmore, 6th; Huntingdon, 6th; Lancaster, 6th; Coopersburg, 6th; Wilkes-Barre, 6th; Greenville, 5th, 6th; Smethport, 4th, 5th, 6th; Philadelphia, 6th; Girardville, 4th, 6th; Selins Grove, 6th; Wellsboro, 5th; Lewisburg, 6th; Columbus, 5th; Dyberry, 6th; Ligonier, 6th; York, 6th; Grampian Hills, 5th; Eagles Mere, 5th.

Frost.—Pittsburg, 4th, 5th, 6th, 7th, 8th, 12th, 13th, 17th; Hamburg, 5th; Blue Knob, 4th, 5th, 7th, 8th, 12th, 13th, 17th, 18th, 19th, 27th; Hollidaysburg, 4th, 5th, 18th; Wysox, 2d, 3d, 4th, 5th, 6th, 8th, 17th, 19th, 27th; Le Roy, 4th, 5th, 6th, 17th, 27th; Quakertown, 2d, 4th, 5th, 6th, 7th, 8th, 10th, 13th, 15th, 16th, 17th, 18th, 19th, 23d, 27th, 28th; Johnstown, 4th, 5th, 8th, 17th, 18th; Emporium, 4th, 13th, 17th, 18th, 27th; State College, 4th; Coatesville, 4th, 5th, 6th; Phoenixville, 4th; Westtown, 6th; Rimersburg, 4th, 5th, 12th, 13th, 17th, 18th, 27th; Lock Haven, 4th, 5th, 6th; Carlisle, 4th; Swarthmore, 6th; New Castle, 4th, 5th, 7th, 8th, 12th, 13th, 17th, 18th, 27th; Lebanon, 4th; Coopersburg, 4th, 5th, 6th; Wilkes-Barre, 4th, 5th, 19th; Nisbet, 4th, 27th; Pottstown, 4th; Selins Grove, 2d, 4th, 5th, 18th, 27th; Somerset, 4th, 5th, 6th, 8th, 17th, 18th, 19th, 28th; Wellsboro, 2d, 3d, 4th, 5th, 6th, 7th, 8th, 12th, 13th, 14th, 17th, 18th, 27th; Lewisburg, 5th; Dyberry, 2d, 4th, 5th, 6th, 7th, 8th, 13th, 14th, 17th, 18th, 19th, 27th, 28th; Honesdale, 1st, 4th, 6th, 17th, 19th, 27th; South Eaton, 2d, 4th, 5th, 6th, 17th; York, 4th, 5th, 17th; Greenville, 5th, 7th, 12th, 13th, 17th, 27th; Columbus, 4th, 5th, 6th, 7th, 8th, 12th, 13th, 14th, 15th, 17th, 18th, 19th, 27th; Meadville, 4th, 5th, 7th, 12th, 13th, 17th, 27th; Grampian Hills, 4th, 5th, 8th, 12th, 17th, 18th, 27th; Eagles Mere, 27th.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Serv

County.	Station.	Elevation above Sea Level (feet).	Barometer Reduced to Sea Level.			Temperature.												Relative Humidity.	Dew Point.	Precipita	
							Maximum.		Minimum.				Daily Range.								
			Mean.	Highest.	Lowest.	Mean.	Highest.	Date.	Lowest.	Date.	Mean of Maximum.	Mean of Minimum.	Mean.	Greatest.	Date.	Least.	Date.			Total Inches.	Total Snowfall During Month.
Allegheny,[1]	Pittsburgh,	847	30·100	30·320	29·860	58·8	84	10	34	17	68·9	48·8	20·1	34·0	19	5·0	28	62·3	44·2	3·23	. . .
Bedford,	Charlesville,	1,300	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Berks,[1]	Hamburg,	380	. . .	. . .	. . .	59·0	91	11	33	4, 5	71·5	46·6	24·9	42·5	11	11·0	24	. . .	. . .	2·24	. . .
Berks,	Reading,	280	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Blair,[2]	Altoona,	1,181	. . .	. . .	. . .	62·2	86	11	37	6	72·5	51·8	20·7	34·0	23	10·0	30	41·9	38·5	1·97	. . .
Blair,	Blue Knob,	2,500	. . .	. . .	. . .	56·8	84	10	26	5	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	·31	1·00
Blair,	Hollidaysburg,	947	. . .	. . .	. . .	58·3	92	10	28	5	73·0	43·4	29·6	53·0	10	10·0	24	65·6	45·7	1·95	. . .
Bradford,	Wysox,	718	30·095	30·320	29·872	55·3	87	10	26	4	68·3	40·9	27·4	48·0	10	12·0	24	69·2	44·9	·49	. . .
Bradford,	Le Roy,	1,400	. . .	. . .	. . .	56·0	85	10	26	5	64·6	46·5	18·1	31·0	19	6·0	21	. . .	. . .	1·18	·40
Bucks,	Forks of Neshaminy (29 days),	. . .	. . .	. . .	. . .	58·1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	2·66	. . .
Bucks,	Quakertown,	536	30·050	30·410	29·780	56·5	88	11	31	6	70·0	43·8	26·2	41·3	11	15·0	30	69·9	47·3	2·56	. . .
Cambria,[1]	Johnstown,	1,184	30·109	30·333	29·871	58·3	89	10	33	5, 8	70·9	45·8	25·1	46·0	10	12·0	29	81·1	49·2	3·44	. . .
Cameron,	Emporium,	1,030	. . .	. . .	. . .	59·6	83	9, 10	25	4	70·7	40·8	29·9	46·0	10	8·0	24	. . .	. . .	1·06	. . .
Carbon,[1]	Mauch Chunk (23 days),	550	. . .	. . .	. . .	58·6	90	10	32	6	71·8	45·4	26·4	44·0	10	10·0	24	. . .	. . .	1·24	. . .
Centre,	State College—Agricultural Experiment Station,	1,191	30·023	30·267	29·769	57·1	85	10	31	5, 6	68·5	46·1	22·4	32·0	19	8·0	21	62·1	42·8	1·94	. . .
Chester,	West Chester,	455	30·050	30·418	29·771	58·8	88	11	32	6	68·6	49·6	19·0	30·0	4	7·5	30	65·0	46·7	3·75	. . .
Chester,	Coatesville,	380	. . .	. . .	. . .	58·0	89	10, 11	29	6	70·7	45·6	25·1	44·0	10	11·0	15	. . .	. . .	3·64	. . .
Chester,[1]	Kennett Square,	275	. . .	. . .	. . .	57·6	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1·93	. . .
Chester,	Phœnixville,	183	30·056	30·422	29·805	58·9	89	11	31	6	70·0	47·7	22·3	37·5	11	10·0	26	73·4	49·8	2·74	. . .
Chester,	Westtown,	350	30·071	30·421	29·720	58·6	88	11	33	6	69·5	49·5	20·0	35·5	10	7·5	15	. . .	. . .	3·04	. . .
Clarion,	Rimersburg,	1,500	. . .	. . .	. . .	56·0	82	19	29	5	65·3	47·4	17·9	33·0	27	4·0	24	. . .	. . .	. . .	. . .
Clarion,	Clarion—State Normal School,	1,530	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Clearfield,	Grampian Hills,	1,450	. . .	. . .	. . .	56·1	78	10, 19	28	5	67·2	45·9	21·3	36·0	18	2·0	24	. . .	. . .	1·29	·30
Clinton,	Lock Haven,	560	. . .	. . .	. . .	58·3	88	10	31	4, 5, 17	70·6	44·4	26·2	43·0	10	9·0	24	. . .	. . .	1·27	. . .
Columbia,	Catawissa,	491	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Crawford,	Meadville,	1,300	. . .	. . .	. . .	52·3	80	10	27	5	64·5	40·3	24·0	41·0	19	9·3	22	77·0	45·0	1·93	1·50
Cumberland,	Carlisle,	480	. . .	. . .	. . .	59·2	93	10	33	4	73·1	46·9	26·2	47·0	10	5·0	24	79·0	51·0	2·17	. . .
Dauphin,[1]	Harrisburg,	361	30·064	30·373	29·843	59·6	89	10	36	6	70·0	50·0	20·0	32·0	10	6·0	23	61·4	44·8	1·77	. . .
Delaware,	Swarthmore—Swarthmore College,	190	30·041	30·395	29·817	59·4	89	11	30	6	70·4	49·7	20·7	49·7	9	7·9	16	68·0	49·0	2·12	. . .
Erie,[1]	Erie,	681	30·070	30·240	29·840	53·0	80	20	32	5	60·0	45·0	15·0	27·0	15	6·0	16	73·0	45·0	1·49	. . .
Fayette,	Uniontown,	1,000	30·065	30·249	29·855	59·8	83	20, 22	34	5, 7	70·1	45·0	25·1	45·0	19	3·0	28	. . .	. . .	3·38	. . .
Franklin,[1]	Chambersburg—Wilson Female College,	618	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Fulton,	McConnellsburg,	875	. . .	. . .	. . .	59·3	93	10	31	18	72·5	47·6	24·9	48·0	10	8·0	24	63·4	35·8	1·71	. . .
Huntingdon,[1]	Huntingdon—The Normal College,	650	. . .	. . .	. . .	58·2	91	10	30	4, 5	72·7	43·8	28·9	46·0	10	15·0	6	. . .	. . .	1·89	. . .
Indiana,	Indiana—State Normal School,	1,350	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Lancaster,	Lancaster—Franklin and Marshall College,	413	30·048	30·300	29·213	59·0	87	10, 11	32	6	70·3	46·3	24·0	38·0	10	11·0	27	72·0	48·5	2·48	. . .
Lawrence,	New Castle,	932	. . .	. . .	. . .	57·5	87	10	24	17	70·2	40·1	30·1	48·0	12	11·0	23	. . .	. . .	2·42	. . .
Lebanon,	Lebanon,	474	30·074	30·399	29·808	59·2	90	11	32	4	71·6	46·2	25·4	44·4	10	9·7	24	70·2	47·9	3·00	. . .
Lehigh,	Coopersburg,	520	. . .	. . .	. . .	58·5	86	10, 11	34	6	68·3	47·5	20·8	33·0	11	10·0	24	. . .	. . .	2·25	. . .
Luzerne,	Drifton—Drifton Hospital,	1,655	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Luzerne,[1]	Wilkes-Barre,	575	. . .	. . .	. . .	58·7	90	10	31	4, 5, 6	72·2	45·3	26·9	44·0	9	12·0	21	. . .	. . .	1·53	·50
Lycoming,[1]	Nisbet,	550	. . .	. . .	. . .	57·8	80	20	30	5	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1·20	. . .
McKean,	Smethport,	1,500	. . .	. . .	. . .	53·7	84	10	24	17	65·8	38·6	27·2	46·0	19	8·0	5	. . .	. . .	. . .	. . .
Mercer,[1]	Greenville—Thiel College,	1,000	30·047	30·342	29·854	54·1	82	10	25	5	66·9	41·3	25·6	39·5	13	7·7	29	83·0	45·4	3·31	·50
Montgomery,	Pottstown,	150	. . .	. . .	. . .	60·5	90	10, 11	36	4	72·0	50·0	22·0	40·0	11	7·0	16	73·0	50·2	2·28	. . .
Northampton,	Bethlehem,	360	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Philadelphia,[1]	Philadelphia—Signal Office,	117	30·047	30·420	29·760	61·0	90	11	36	6	70·1	51·8	18·3	30·0	11	7·0	23	63·0	45·0	1·74	. . .
Philadelphia,	Philadelphia,	120	30·057	30·432	29·771	61·7	91	11	35	6	71·7	51·7	20·0	31·5	10	8·0	24	77·0	50·3	2·01	. . .
Schuylkill,	Girardville,	1,000	30·010	30·312	29·827	57·3	85	10	31	6	67·8	45·0	22·8	40·0	10	9·0	24	. . .	. . .	1·80	. . .
Snyder,	Selins Grove,	445	30·066	30·343	29·804	59·7	92	10	. . .	. . .	74·1	45·4	28·7	. . .	. . .	. . .	. . .	79·6	53·7	1·36	.50
Somerset,	Somerset,	2,250	. . .	. . .	. . .	53·4	88	10	26	5	67·0	41·0	26·0	46·0	10	10·0	20	78·3	48·2	4·10	. . .
Sullivan,	Eagles Mere,	2,000	30·112	30·359	29·934	52·3	78	9, 10	26	10	60·8	44·7	16·1	34·0	9	4·0	6	69·1	43·1	2·67	. . .
Tioga,	Wellsboro,	1,327	30·034	30·299	29·776	51·0	84	10	23	4	63·6	39·5	24·1	40·0	15	2·0	18	64·2	38·4	1·25	1·50
Union,[1]	Lewisburg,	450	. . .	. . .	. . .	60·4	91	10	31	6	74·3	46·3	27·8	43·0	10	3·0	24	. . .	. . .	·67	. . .
Warren,	Columbus,	1,410	. . .	. . .	. . .	52·2	84	31	24	13, 17	66·3	38·1	28·2	50·0	13	8·0	5	60·0	36·0	1·58	2·00
Washington,	Canonsburg,	950	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Wayne,	Dyberry,	1,100	. . .	. . .	. . .	52·0	84	10	20	4	66·2	38·8	27·4	43·0	4	12·0	21	. . .	. . .	2·27	1·00
Wayne,	Honesdale,	1,000	. . .	. . .	. . .	54·9	82	10	29	5, 16	67·1	42·8	24·3	30·0	10	10·0	22	70·4	44·8	1·92	. . .
Westmoreland,	Ligonier,	1,750	. . .	. . .	. . .	60·0	87	10	27	18	70·2	49·8	20·4	51·0	10	10·0	23	72·0	50·0	4·41	. . .
Wyoming,[1]	South Eaton	660	. . .	. . .	. . .	55·2	85	10	26	2	67·0	43·4	23·6	42·0	2	13·0	6	. . .	. . .	1·06	. . .
York,[1]	York,	385	30·035	30·401	29·818	59·8	92	10	32	4	73·2	46·5	26·7	46·5	10	11·0	24	74·1	50·9	2·39	. . .

[1] Observations taken at 8 A. M. and 8 P. M. [2] Observations taken at 12 Noon.

TEMPERATURE.											PRECIPITATION.		
MINIMUM.				DAILY RANGE.									
Lowest.	Date.	Mean of Maximum.	Mean of Minimum.	Mean.	Greatest.	Date.	Least.	Date.	Relative Humidity.	Dew Point.	Total Inches.	Total Snowfall During Month.	Number of Days Rainfall.
34	17	68·9	48·8	20·1	34·0	19	5·0	28	62·3	44·2	3·23	. . .	10
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
33	4, 5	71·3	46·6	24·9	42·5	11	11·0	24	. . .	. . .	2·24	. . .	7
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
37	6	72·5	51·8	20·7	34·0	23	10·0	30	41·9	38·5	1·97	. . .	8
26	5	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	·31	1·00	11
28	5	73·0	43·4	29·6	53·0	10	10·0	24	65·6	45·7	1·95	. . .	8
26	4	68·3	40·9	27·4	48·0	10	12·0	24	69·2	44·9	·49	. . .	7
26	5	64·6	46·5	18·1	31·0	19	6·0	21	. . .	. . .	1·18	·40	6
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	2·66	. . .	12
31	6	70·0	43·8	26·2	41·3	11	15·0	30	69·9	47·3	2·56	. . .	10
33	5, 8	70·9	45·8	25·1	46·0	10	12·0	29	81·1	49·2	3·44	. . .	10
25	4	70·7	40·8	29·9	46·0	10	8·0	24	. . .	. . .	1·00	. . .	5
32	6	71·8	45·4	26·4	44·0	10	10·0	24	. . .	. . .	1·24	. . .	6
31	5, 6	68·5	46·1	22·4	32·0	19	8·0	21	62·1	42·8	1·94	. . .	6
32	6	68·6	49·6	19·0	30·0	4	7·5	30	65·0	46·7	3·75	. . .	15
29	6	70·7	45·6	25·1	44·0	10	11·0	15	. . .	. . .	3·64	. . .	11
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1·93	. . .	9
31	6	70·0	47·7	22·3	37·5	11	10·0	26	73·4	49·8	2·74	. . .	13
33	6	69·5	49·5	20·0	35·5	10	7·5	15	. . .	. . .	3·04	. . .	7
29	5	65·3	47·4	17·9	33·0	27	4·0	24	. . .	. . .	. . .	. . .	11
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
28	5	67·2	45·9	21·3	36·0	18	2·0	24	. . .	. . .	1·29	·30	8
31	4, 5, 17	70·6	44·4	26·2	43·0	10	9·0	24	. . .	. . .	1·87	. . .	3
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
27	5	64·5	40·5	24·0	41·0	19	9·5	22	77·0	45·0	1·93	1·50	6
33	4	73·1	46·9	26·2	47·0	10	5·0	24	79·0	51·0	2·17	. . .	8
36	6	70·0	50·0	20·0	32·0	10	6·0	23	61·4	44·8	1·77	. . .	10
30	6	70·4	49·7	20·7	49·7	9	7·9	16	68·0	49·0	2·12	. . .	7
32	5	60·0	45·0	15·0	27·0	15	6·0	16	73·0	45·0	1·49	. . .	11
34	5, 7	70·1	45·0	25·1	45·0	19	3·0	28	. . .	. . .	3·38	. . .	8
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
31	18	72·5	47·6	24·9	48·0	10	8·0	24	63·4	35·8	1·71	. . .	6
30	4, 5	72·7	43·8	28·9	46·0	10	15·0	6	. . .	. . .	1·89	. . .	7
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
32	6	70·3	46·3	24·0	38·0	10	11·0	27	72·0	48·3	2·48	. . .	9
24	17	70·2	40·1	30·1	48·0	12	11·0	23	. . .	. . .	2·42	. . .	9
32	4	71·6	46·9	25·4	44·4	10	9·7	24	70·2	47·9	3·00	. . .	11
34	6	68·3	47·5	20·8	33·0	11	10·0	24	. . .	. . .	2·25	. . .	9
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
31	4, 5, 6	72·2	45·3	26·9	44·0	9	12·0	21	. . .	. . .	1·53	·50	5
30	5	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1·20	. . .	4
24	17	65·8	38·6	27·2	46·0	19	8·0	5	. . .	. . .	. . .	. . .	. . .
25	5	66·9	41·3	25·6	39·5	13	7·7	29	83·0	45·4	3·31	·50	12
30	4	72·0	50·0	22·0	40·0	11	7·0	16	73·0	50·2	2·28	. . .	9
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
36	6	70·1	51·8	18·3	30·0	11	7·0	23	63·0	45·0	1·74	. . .	12
35	6	71·7	51·7	20·0	31·5	10	8·0	24	77·0	50·3	2·01	. . .	12
31	6	67·6	45·0	22·8	40·0	10	9·0	24	. . .	. . .	1·80	. . .	11
. . .	. . .	74·1	45·4	28·7	. . .	. . .	. . .	. . .	79·6	53·7	1·36	.50	7
26	5	67·0	41·0	26·0	46·0	10	10·0	20	78·3	48·2	4·10	. . .	6
26	10	60·8	44·7	16·1	34·0	9	4·0	6	69·1	43·1	2·67	. . .	5
23	4	63·6	39·5	24·1	40·0	13	2·0	18	64·2	38·4	1·25	1·50	5
31	6	74·3	46·5	27·8	43·0	10	9·0	24	. . .	. . .	·67	. . .	3
24	13, 17	66·3	38·1	28·2	50·0	13	8·0	5	60·0	36·0	1·58	2·00	7
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
20	4	66·2	38·8	27·4	43·0	4	12·0	21	. . .	. . .	2·27	1·00	8
29	5, 16	67·1	42·8	24·3	30·0	10	10·0	22	70·4	44·8	1·92	. . .	7
27	18	70·2	49·8	20·4	51·0	10	10·0	23	72·0	50·0	4·41	. . .	6
26	2	67·0	43·4	23·6	42·0	2	13·0	6	. . .	. . .	1·06	. . .	7
32	4	73·2	46·5	26·7	46·5	10	11·0	24	74·1	50·9	2·39	. . .	13

ITATION.		NUMBER OF DAYS.			WIND.			OBSERVERS.
During Month.	Number of Days Rainfall.	Clear.	Fair.	Cloudy.	PREVAILING DIRECTION. 7 A. M.	2 P. M.	9 P. M.	
. .	10	8	8	15	W	W	W	Oscar D. Stewart, Sgt. Sig. Corps.
. .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Miss E. A. G. Apple.
. .	7	8	14	9	W	W	NW	William Shipe.
. .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Franklin Yager.
. .	8	. . .	. . .	. . .	. . .	. . .	. . .	Dr. Charles B. Dudley.
00	11	10	13	8	NW	NW	NW	A. H. Boyle.
. .	8	19	3	9	W	W	E	Prof. J. A. Stewart.
. .	7	13	4	14	E	NW	NW	Charles Beecher.
40	6	7	14	10	SW	SW	SW	Geo. W. T. Warburton
. .	12	11	9	9	N	W	W	J. C. Hilsman.
. .	10	7	11	13	NW	SW	SW	J. L. Heacock.
. .	10	6	13	12	. . .	. . .	. . .	E. C. Lorentz.
. .	5	12	7	12	NW	NW	W	T. B. Lloyd.
. .	6	7	10	6	NW	NW	NW	John J. Boyd.
. .	6	3	14	12	W	W	W	Prof. Wm. Frear.
. .	15	12	7	12	NW	W	S	Jesse C. Green, D.D.S.
. .	11	8	13	10	W	W	W	W. T. Gordon.
. .	9	8	11	12	NW	. . .	SE	Benj. P. Kirk.
. .	13	7	8	16	NW	NW	NW	Knowles Croskey.
. .	7	5	15	11	W	W	W	Prof. Wm. F. Wickersham.
. .	11	11	9	11	W	W	W	Rev. W. W. Deatrick, A.M.
. .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	C. M. Thomas, B.S.
30	8	12	9	10	NW	SW	NW	Nathan Moore.
. .	3	11	11	10	W	W	W	Prof. John A. Robb.
. .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Robert M. Graham.
50	6	13	13	5	NW	N	W	J. & B. H. Metcalf.
. .	8	9	12	10	S	SW	S	J. E. Pague.
. .	10	8	8	15	NW	NW	NW	Frank Ridgway, Sgt. Sig. Corps.
. .	7	1	16	14	W	W	W	Prof. Susan J. Cunningham.
. .	11	11	9	11	NW	NW	NW	Peter Wood, Sgt. Sig. Corps.
. .	8	15	11	5	. . .	. . .	. . .	Wm. Hunt.
. .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Miss Mary A. Ricker.
. .	6	12	9	10	N	N	N	Thomas F. Sloan.
. .	7	9	12	10	W	W	W	Prof. W. J. Swigart.
. .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. S. C. Schmucker.
. .	9	6	10	15	NW	NW	NW	Lewis T. Lampe.
. .	9	13	7	11	NW	E	NW	Wm. T. Butz.
. .	11	6	17	8	NE	SW	SW	Geo. W. Hayes, C.E.
. .	9	4	15	12	SE	NW	NE	M. H. Boye.
. .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	H. D. Miller, M.D.
50	5	16	2	13	NW	NW	NW	A. W. Betterly.
. .	4	10	8	13	. . .	. . .	. . .	John S. Gibson, P. M.
. .	. . .	16	6	9	S	S	S	Armstrong & Brownell.
50	12	11	11	9	NW	NW	NW	Prof. S. H. Miller.
. .	9	17	5	9	W	W	W	Charles Moore, D.D.S.
. .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Lerch & Rice.
. .	12	9	5	17	NW	NW	NW	Luther M. Dey, Sgt. Sig. Corps.
. .	12	5	16	10	NW	SW	SW	John Comly.
. .	11	18	8	5	NW	NW	NW	E. C. Wagner.
50	7	12	12	7	SW	SE	SE	J. M. Boyer,
. .	6	9	10	12	NW	NW	NW	W. M. Schrock.
. .	5	10	12	9	NW	NW	NW	E. S. Chase.
1'50	5	8	11	12	N	N	N	H. D. Deming.
. .	3	10	17	4	SW	SW	SW	F. O. Whitman.
2'00	7	12	12	7	W	W	W	Wm. Loveland.
. .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	A. L. Runion, M.D.
1'00	8	8	14	9	NW	NW	NW	Theodore Day.
. .	7	. . .	. . .	. . .	. . .	. . .	. . .	John Torrey.
. .	6	18	4	9	. . .	. . .	. . .	J. T. Ambrose.
. .	7	11	11	9	NW	NW	NW	Benj. M. Hall.
. .	13	13	10	8	NW	NW	NW	Mrs. L. H. Grenewald.

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Sleet.—Blue Knob, 4th, 6th; New Castle, 5th; Wellsboro, 6th; Ligonier, 4th.

Coronæ.—Blue Knob, 19th; Lebanon, 1st, 2d, 8th, 13th, 14th, 15th, 16th, 17th, 19th, 20th, 21st, 22d; Somerset, 22d.

Solar Halos.—Hollidaysburg, 2d; Le Roy, 1st, 2d, 13th, 25th, 27th, 28th; State College, 16th; Rimersburg, 27th; Huntingdon, 13th; Philadelphia, 13th, 27th; Dyberry, 23d, 25th, 28th; Eagles Mere, 20th, 23d, 27th.

Lunar Halos.—Blue Knob, 18th; Phœnixville, 13th; Carlisle, 13th, 14th; Lancaster, 20th; Somerset, 19th, 21st; York, 19th; Meadville, 16th, 19th, 20th.

Meteors.—State College, 5th.

Parhelias.—Dyberry, 2d; Eagles Mere, 23d.

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Percentage of local verifications of weather and temperature signals as reported by displaymen for May, 1891:

Weather, 85 per cent.
Temperature, 91 per cent.

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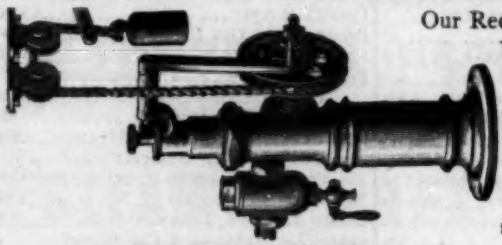

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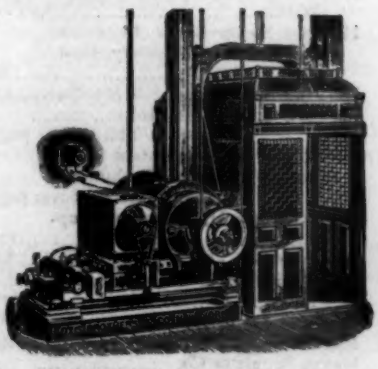

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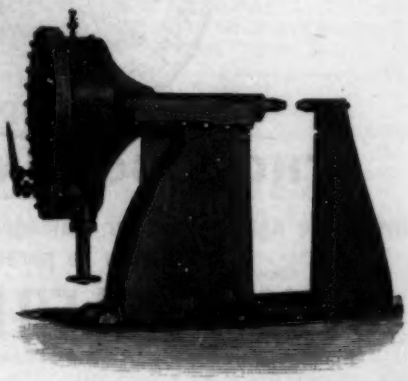

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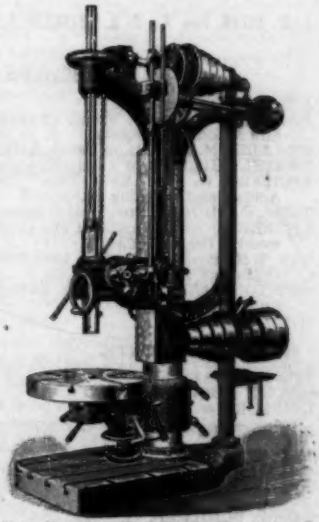

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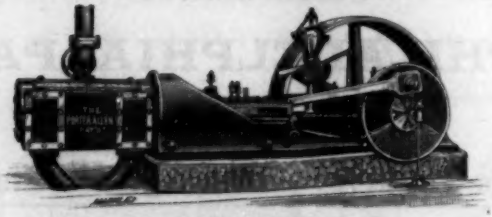

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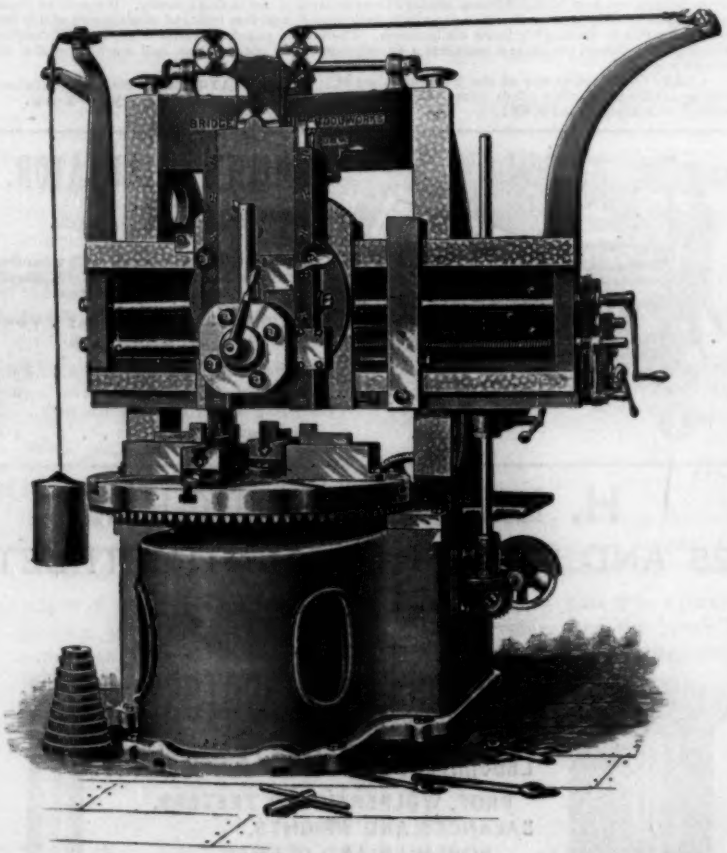

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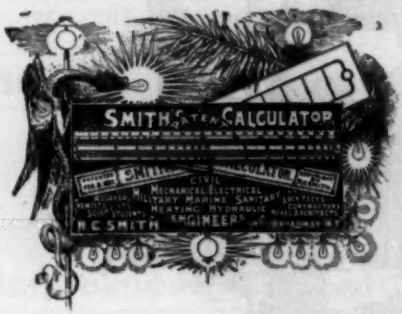

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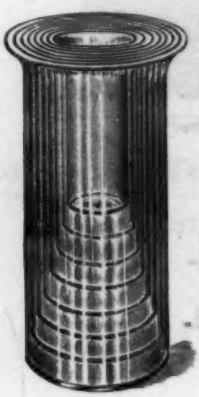

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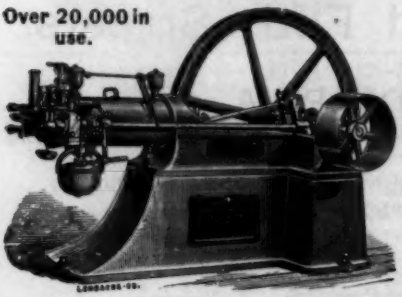

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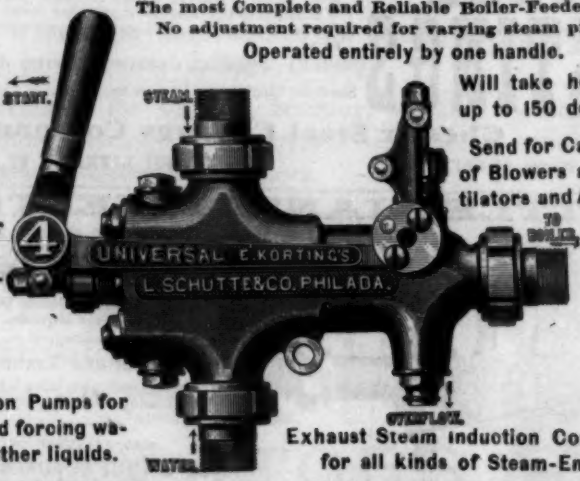

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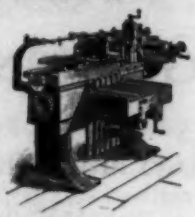

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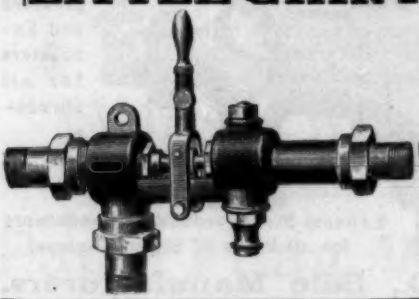

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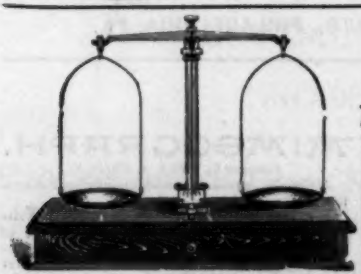

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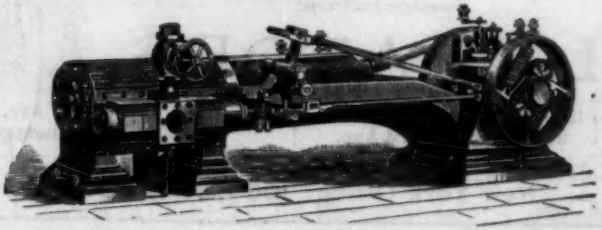
TRENTON  ENGINE

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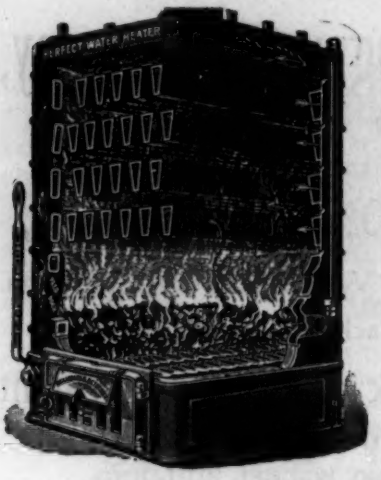

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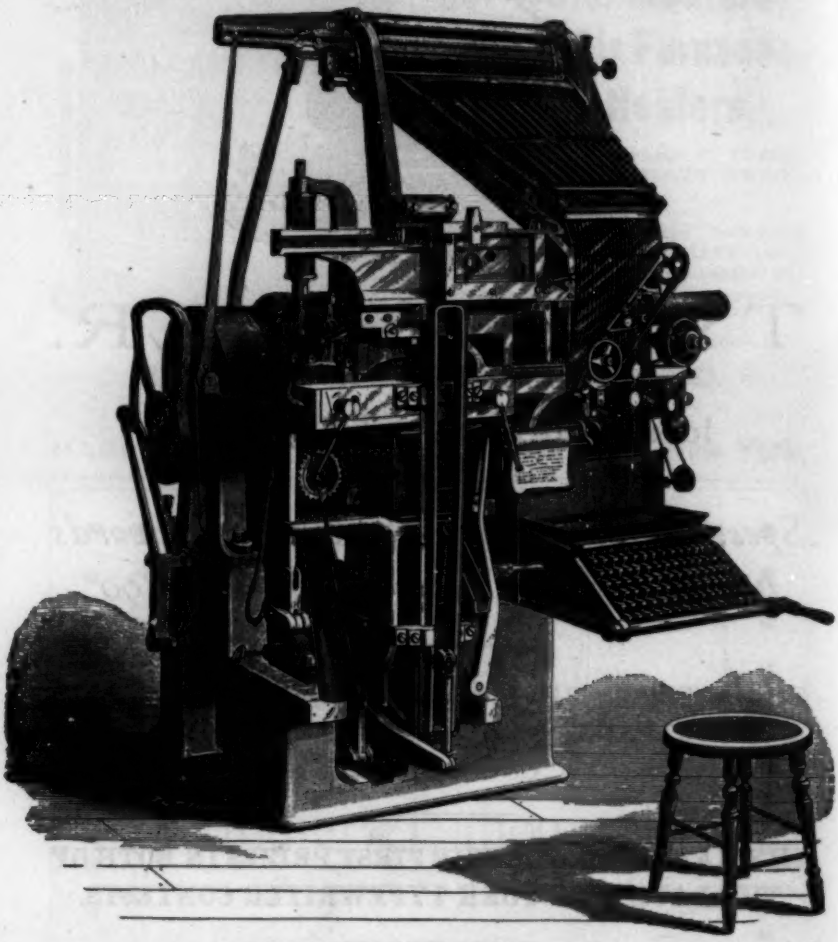

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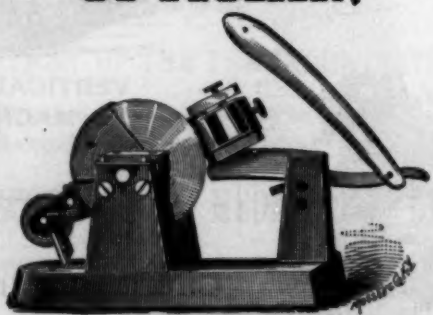

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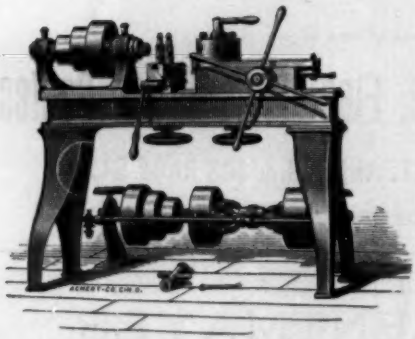

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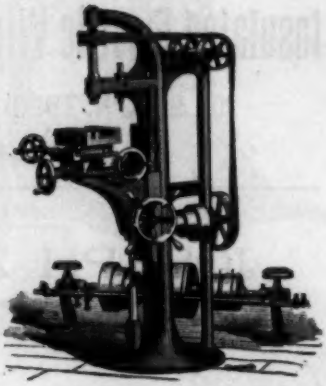

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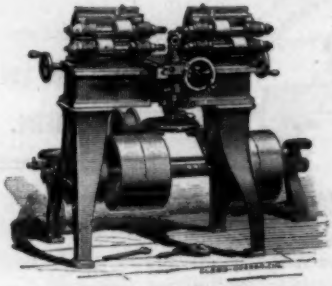

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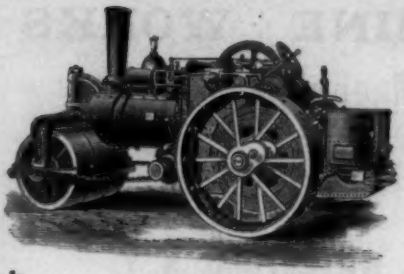

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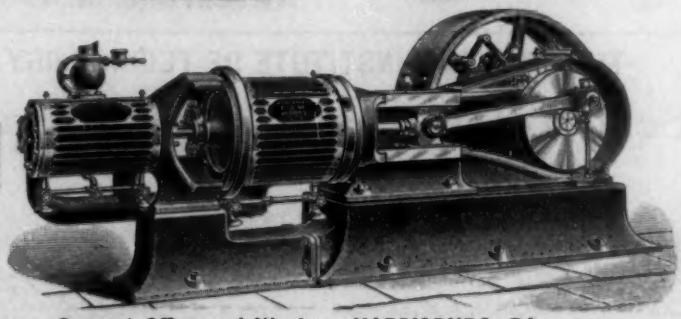

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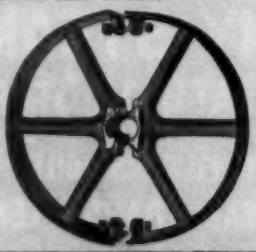

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